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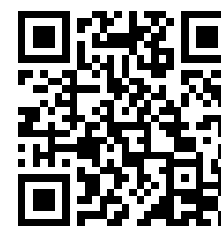

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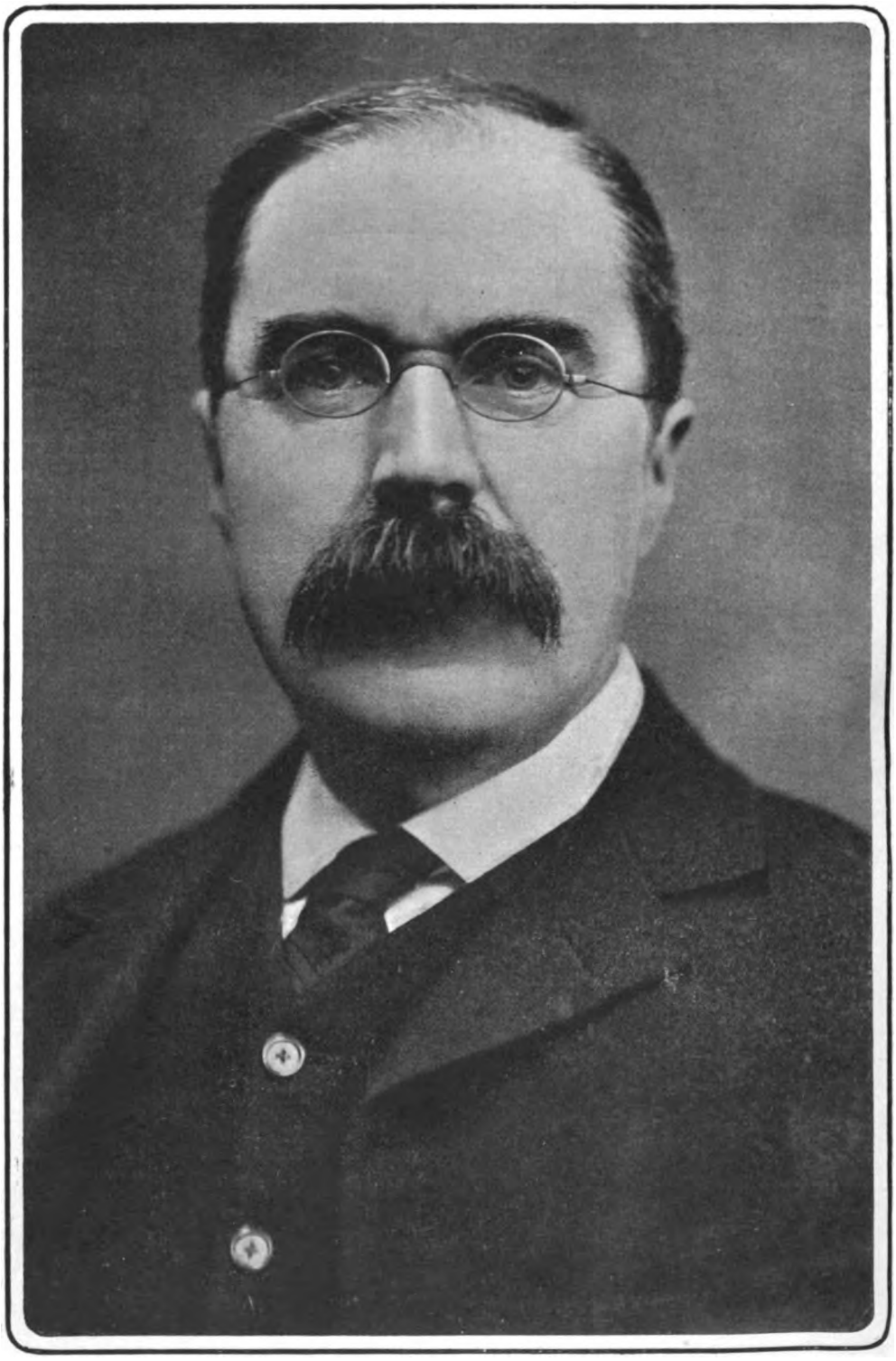

R. H. HOUSMAN, B.Sc., M.I.E.E.

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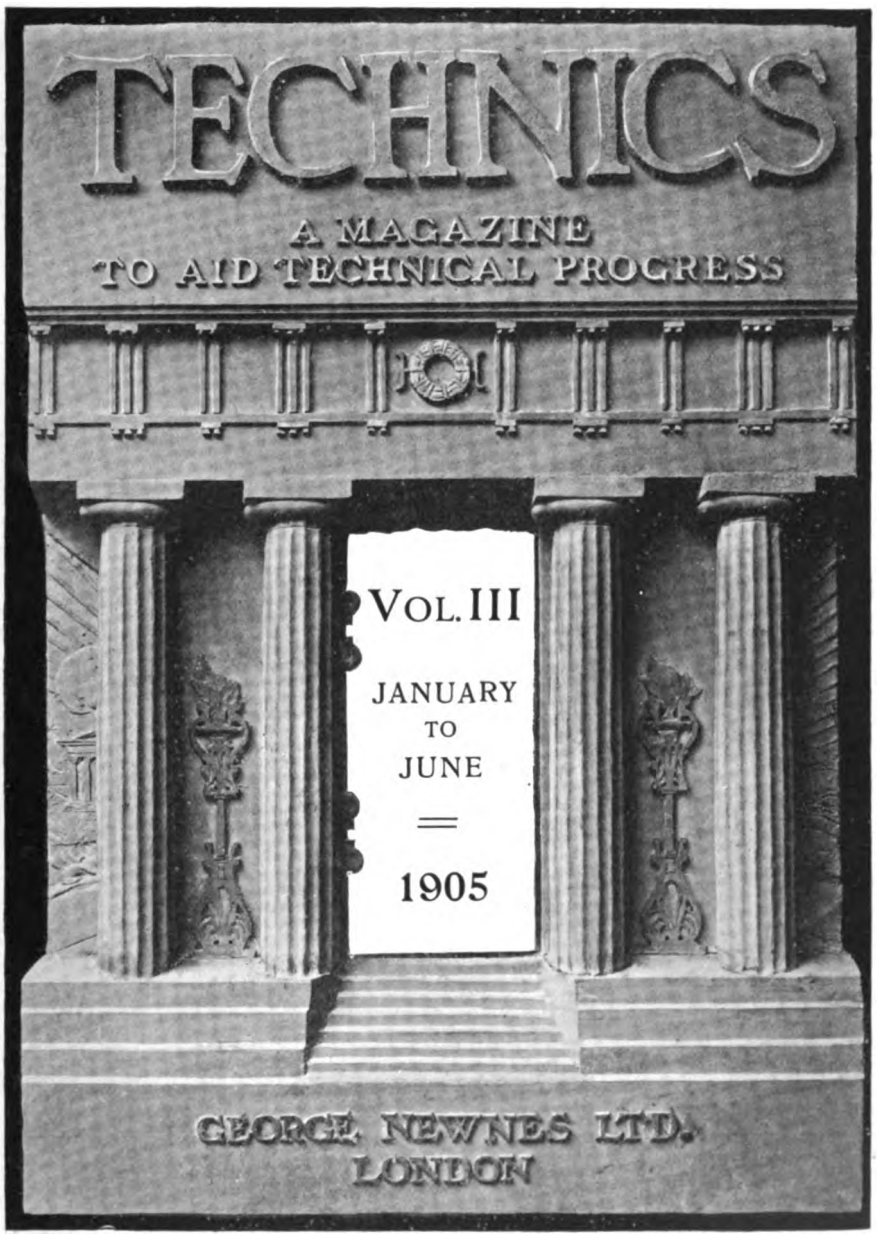

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

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PROGRESS OF SCIENCE AND TECHNOLOGY.

EVERYONE realises the importance of considering the nature of the subsoil in choosing a site for a house, or in planning the foundations if no choice is allowed; but few get beyond sweeping generalisations of different soils as good or bad. In reality, the decision on the goodness or badness of a site depends upon considerations more complex than the mere mineral nature of the subsoil. Those who wish for guidance on this subject cannot do better than to consult a fifty-eight-page pamphlet entitled "Soils and Subsoils," written by Mr. Horace B. Woodward, F.R.S., and published by the Geological Survey. While explaining the general principles that hold everywhere, it illustrates them by special reference to the very varied series of subsoils found in "Greater London," each of which is described in the detailed manner that the author's long experience and the mass of information accumulated by the survey makes possible. Among points of interest not usually known we may refer to the discussion on the importance of "made ground" in districts that have long been occupied; and to the cases of gravels of which the matrix is so clayey that they are almost impermeable to water: and the dangers of foundering where a thin covering of gravel or loam rests upon chalk. The obtaining of a firm and dry foundation, and the problems of water supply and drainage that are so serious in rural districts, are all dealt with very lucidly, and even the suitability of soils for gardens is not forgotten. This little book is illustrated by many figures, and by a coloured map, in which the subsoils are coloured according to their mineral nature, not (as usual on geological maps) according to geological age. As this map extends from Windsor to Gravesend and St. Albans to Dorking, it gives a good general view of the whole country accessible for residence to Londoners; but as it is on the scale of four miles to an inch, it is of little use where some definite site is under consideration. In such cases reference should be made to the new geological maps on the scale of an inch to the mile, of which the four London sheets have recently been published (revised) at *7s. 6d.* each, or, if possible, to the MS. six-inch maps which can be consulted at Jermyn Street Museum, but of which there are very few prepared for the London district. To those concerned with areas that have been recently surveyed (*e.g.*, the South Wales and North Staffordshire coalfields), these MS. six-inch maps will be a great boon.

Soils and Subsoils

THE rough usage to which tramway rails are subjected by the heavy and high-speed electric cars of the present day, and the variety of other traffic that passes over them, renders most stringent testing before acceptance from the manufacturer a matter of necessity. The usual tests applied are four in number, *viz.*: chemical analysis, bending test, impact test, and tensile test. The first is made upon drillings taken from the tensile test piece, and is for the purpose of determining the relative proportions of the various chemicals used in the manufacture of steel rails. As the constituents of a rail have a great bearing upon its life, this test is one of importance, and every rolling of up to 100 tons is subjected to it.

Testing Tramway Rails

The bending test, like all the others, is severe; it generally calls for the bending by pressure of a cold rail sideways to a curve of

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30 feet radius, which should not result in any appearance of cracking. Should this, however, take place, the British standard specification allows two more chances, and a couple of rails are taken from the same 100-ton rolling and subjected to the test. If they also fail, the entire rolling from that cast may be rejected.

The impact test is applied to one out of every eighty rails, a length of 5 feet being cut off and supported head uppermost on substantial iron blocks placed 3 feet 6 inches apart. A blow is then administered to the centre of the rail by a spherically ended weight of not less than one ton, the radius of its nose not being more than 9 inches. For rails up to a hundred pounds a yard, the weight has a fall of 15 feet; but for all heavier than this, a drop of 18 feet is usual. Should fracture be the result of the blow, two more rails are tested in a similar manner, the failure of which justifies the rejection of the entire cast.

The tensile test consists of taking a sample piece from each 100-ton lot of rails, and preparing it so that its sectional area is approximately half a square inch, and its length sufficient to allow of a 2-inch distance between the test gauge points. Under test, its ultimate tensile strength must prove to be not less than 40 tons per square inch, and its elongation, at the lowest, 12 per cent. in the given 2-inch length. In the event of failure, a second test is allowed, and if the result is similar, the entire cast is rejected. All the above conditions represent standard British practice, but they are often departed from in detail, and sometimes further tests are imposed.

The Winding of Rivers

THE tendency of a river to follow a sinuous instead of a straight course is proverbial: the River Meander, in Phrygia, noted for its involved course, has given us a useful word expressive of an indirect course. The reason why rivers tend to wind was explained many years ago by the late James Thomson, brother of Lord Kelvin; nevertheless, the subject is understood to-day by a smaller number of people than might be expected from the importance and interest of the subject.

When a river flows round a bend (Fig. 1), each particle of water revolves about a point, with the consequence that the centrifugal force called into play causes the level of the water on the concave side of the bend to be higher than that of the convex side. The water, of course, tends to flow back from the higher to the lower level, but is prevented from doing so by the centrifugal force acting on it. Very close to the concave bank of the river, friction diminishes the speed of the water, with the result that the level of the surface there becomes lower (Fig. 2); as a consequence, the water flows downwards at the concave side, scooping out mud from the bank, which it deposits on the convex side of the river. Accordingly, if a river has the smallest possible bend in its course, there is a tendency for this bend to increase; the banks are cut away on the concave side, and

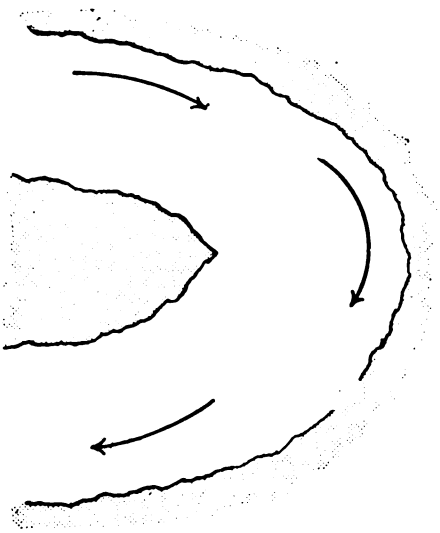

FIG. 1.—PLAN OF RIVER BEND.

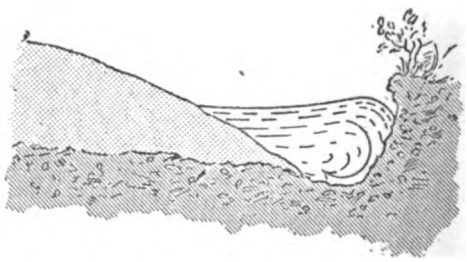

FIG. 2.—SECTION THROUGH RIVER BEND.

mud is deposited on the convex side. Fig. 3 is from a photograph of the valley of the Tay; the spit of mud on the convex side of the bend is very noticeable in comparison with the steeper bank on the concave side. The principles just discussed can be illustrated, if some tea containing "grounds" is placed in a saucer and then set in rotation by the aid of a spoon. It will be noticed that the grounds are carried to the middle of the saucer and deposited there. On the other hand, if the saucer is supported on a turn-table which is then set in rotation, the speed of

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the water near the edge of the saucer will be greater than that near its centre; with the result that the grounds will be carried outwards from the middle of the saucer and deposited near its edge.

"Hardness" in Water

"HARD" water is really a dilute aqueous solution of certain salts, chiefly calcium bicarbonate, calcium sulphate, and magnesium chloride; the presence of one or all of these substances in water will render it more or less "hard," according to the amount dissolved in a given volume of water. "Hardness" is measured by the amount of soap which can be decomposed by the salts in a gallon of water; thus water of "1° of hardness" is such that the salts in a gallon of it will decompose as much soap as can be decomposed by one grain of carbonate of lime.

It is well known that the use of hard water in steam boilers entails serious disadvantages: while the water is converted into steam, the salts remain in the boiler, forming a layer of "scale" which progressively increases in thickness. Eventually it becomes necessary to remove this scale, with the result that the boiler must be thrown out of use for a time; further, the operation of chipping off the scale especially when this is mainly composed of calcium sulphate, is one of some considerable difficulty; also, the boiler and the surrounding brickwork must have been allowed to cool down before the scale could be removed, and an extra amount of coal is required to again bring the boiler and brickwork up to their working temperature. There is yet another disadvantage of a serious character: the layer of scale on the boiler is a bad conductor of heat, with the result that when the water is kept at a constant temperature, the greater the thickness of the scale, the higher the temperature of the surface of the boiler plates or tubes in contact with the flue gases; these higher temperatures entail increased wear and tear, and considerably shorten the life of the boiler.

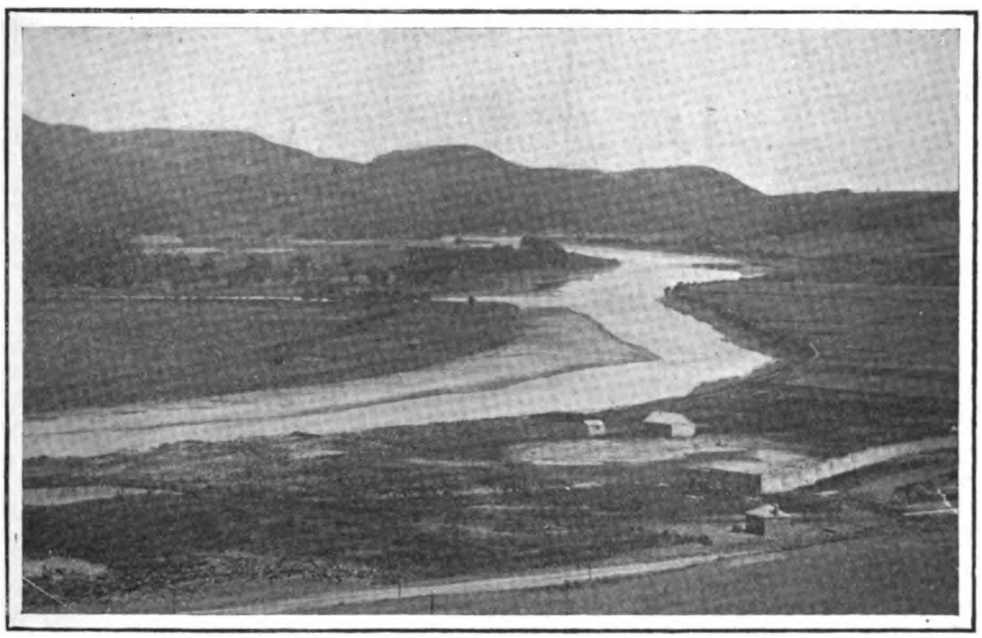

Photo by [*Frith.*

FIG. 3.—VIEW IN THE VALLEY OF THE TAY, SHOWING THE CHARACTER OF A RIVER BEND.

Softening Water with Soap

THE use of hard water in the laundry is equally disadvantageous; before a lather suitable for washing clothes can be obtained, a certain amount of soap must be used up in decomposing the salts, and the calcium stearate produced as a result of this decomposition is deposited in the fibres of the clothes, rendering their colour "bad." To soften water by the aid of soap, about 1¼ lbs. of soap is required per gallon of water for each degree of hardness; thus with a water

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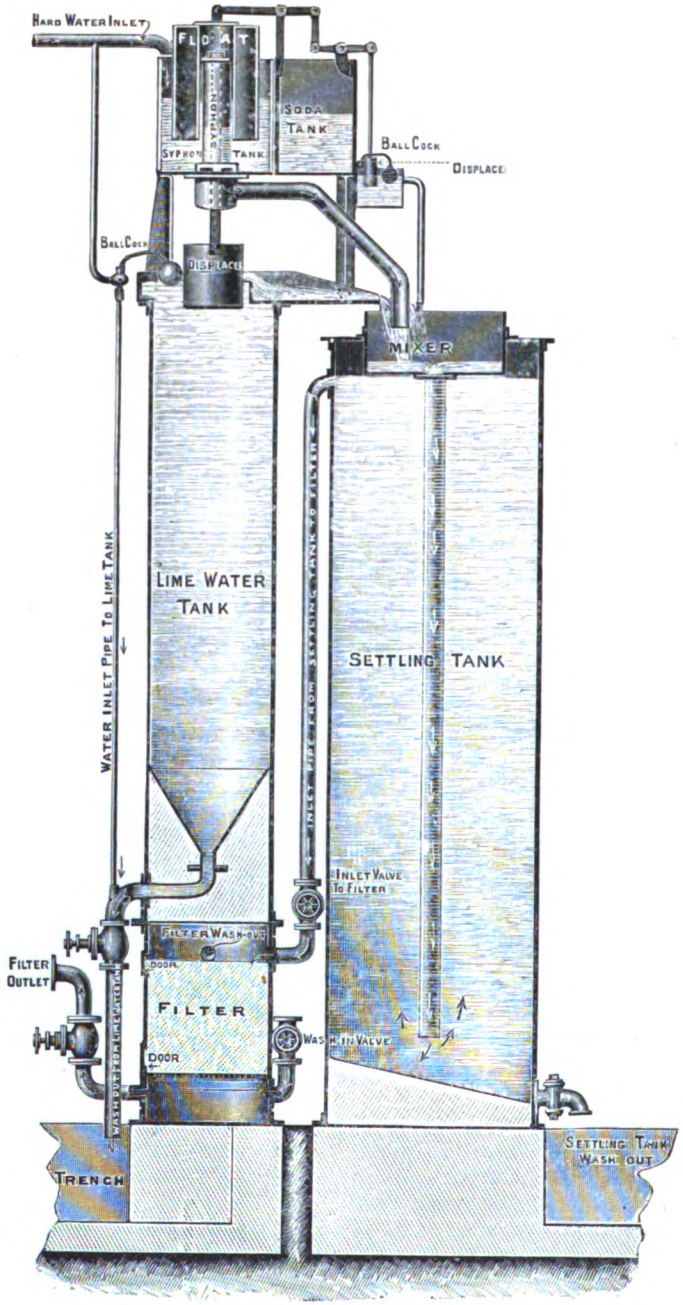

Fig. 4.—The "Criton" Water Softener.

of 10° of hardness, 17½ lbs. of soap must be used per gallon of water before a lather can be produced, while only about 1¾ lbs. of soap per gallon of water is required to make the lather: consequently, more than 90 per cent. of the soap has been used merely to soften the water. Using soap at 2*d.* per lb. to soften water of 10° hardness, the cost per gallon works out at about 2*s.* 11*d.* per thousand gallons; on the other hand, the water could be softened chemically, by the means subsequently to be described, at a cost of a few half-pence per thousand gallons.

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THE bicarbonate of calcium in water can be thrown out of solution by boiling; carbon-dioxide is expelled, leaving calcium carbonate, which is insoluble, behind, according to the equation

Chemical Softening of Water

$$CaH_2(CO_3)_2 = CaCO_3 + H_2O + CO_2.$$

Thus calcium bicarbonate is said to impart "temporary hardness" to water.

It is more economical to convert the calcium bicarbonate into calcium carbonate by the aid of a solution of calcium hydrate, according to the equation

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O.$$

Permanent hardness is imparted to water by the presence of calcium chloride, calcium sulphate, magnesium chloride, and magnesium sulphate; these compounds are not precipitated by raising the water to its boiling point. Of the above compounds, only two—calcium sulphate and magnesium chloride—cause much trouble to steam users. Calcium sulphate may most readily be removed by converting it into calcium carbonate by adding carbonate of soda; the reaction is explained by the equation

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$

Calcium chloride can be removed in a similar manner. Magnesium chloride may be converted into insoluble magnesium hydrate by adding sodium hydrate (caustic soda) to the solution, the reaction being as follows:—

$$MgCl_2 + 2NaOH = Mg(OH)_2 + 2NaCl.$$

Magnesium sulphate is removed in a similar manner.

Thus the salts which impart hardness to water can be removed by adding calcium hydrate, sodium carbonate, and caustic soda; but for their removal to be at once economical and effective, the right quantities of the reagents must be added: the addition of too much soda, for instance, entails unnecessary expense, and also damages the boiler.

IN order to soften water on a large scale, it thus becomes necessary to add the amounts of calcium hydrate, sodium carbonate, and caustic soda indicated by the results of an analysis of the water. The "Criton" water softener, manufactured by the Pulsometer Engineering Company, Limited, of Nine Elms Iron Works, Reading, performs this operation automatically. Fig. 4 represents the sectional elevation of the plant. The solution of calcium hydrate is formed in the lime water tank: water enters at the lower conical end of the tank, and passes upwards through a bed of quick lime, thus becoming saturated with calcium hydrate; the tank is always kept full by the aid of the ball-cock shown at the upper end of the tank. The small soda tank is kept full in a similar manner: soda ash and lime are mixed with water in the larger soda tank, thus producing the requisite proportions of sodium carbonate and caustic soda in the solution. The hard water to be softened is fed into the syphon tank at the top of the plant: as the level of its surface rises, the float is raised, thus forcing two displacers downwards, one into the lime tank, and the other into the small soda tank—thus discharging the requisite amounts of the lime and soda solutions into the "mixer." When the level of the water surface in the syphon tank rises to the height of the top of the central tube, the whole of the contents of this tank suddenly syphon over into the mixer, where they mix with the lime and soda solutions. They then pass downwards to the bottom of the settling tank, where the insoluble matter is deposited; the "soft" water rises, leaves the top of the settling tank by a pipe, and after passing through the filter, is ready for use. When the syphon tank discharges its contents, the displacers in the lime and soda tanks rise, thus increasing the amounts of the solutions in these tanks; it is readily seen that, by adjusting the extent to which the displacers can be immersed in their respective tanks, the amounts of the solutions discharged each time the syphon tube is emptied can be controlled at will. When once the displacers have been adjusted, the action of the softening plant is purely automatic, just as much water being softened as is required for use. In the case of a medium-sized plant, the attention required is merely that of one man for an hour, once every twelve hours.

The "Criton" Water Softener

AN ingenious form of barometer has recently been invented by Mr. A. S. Davis, M.A.: the essential features of this instrument are represented diagrammatically in Fig. 5. Mercury is contained in a small metal box or cistern; through one face of the latter the open end of a glass tube of fine bore projects for a short distance, the other end of the tube being bent through two right angles and sealed on to a cylindrical glass vessel. When the instrument is in the position represented in Fig. 5, the open end of the tube lies above the mercury in the cistern, so that the pressure of the air in the

The Piesmic Barometer

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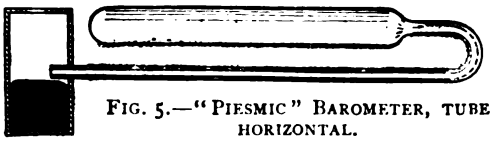

FIG. 5.—"PIESMIC" BAROMETER, TUBE HORIZONTAL.

FIG. 6. "PIESMIC" BAROMETER, TUBE VERTICAL.

tube is equal to that of the air in the cistern; a small aperture in the walls of the cistern, closed with wash-leather, ensures that the pressure in the cistern is always equal to that of the external atmosphere, while the entrance of dust into the cistern, or the loss of mercury from the same, is prevented. On turning the instrument so that the tube becomes vertical (Fig. 6), mercury flows down the tube to a distance which depends on the barometric pressure.

Let V cubic inches be the volume of air at atmospheric pressure contained by the tube and the vessel sealed on to it; if P is the atmospheric pressure, in inches of mercury, then so long as the temperature of the air remains constant, the product of the pressure and volume of this air will remain equal to PV.

When the instrument is turned into the position represented in Fig. 6, the air in the tube is sealed off by the mercury, and compressed as the mercury flows down the tube. Let the mercury surface in the cistern be just flush with the open end of the tube, while the length of the column of mercury in the tube is d inches; then the pressure of the air in the tube is now equal to $(P + d)$ inches. If a square inches is the internal cross-sectional area of the tube, the volume of the air is diminished by ad cubic inches; thus, according to Boyle's Law

$$PV = (P + d)(V - ad)$$

$$PV = PV - Pad + Vd - ad^2$$

$$\therefore\ P = \frac{V}{a} - d.$$

Now V and a are invariable dimensions, so that the barometric pressure is equal to a constant *minus* the distance d, through which the mercury sinks in the tube. Consequently, if a scale graduated in inches, and suitably numbered, is placed behind the tube, the barometric pressure can be read off at a glance. The result is independent of the temperature of the air, provided this does not change between the time when the instrument is turned into a vertical position, and that when the reading is taken. Changes of temperature will, however, affect the readings of the instrument to a very slight extent, owing to the variation in the values of V and a; this variation, however, merely depends on the coefficient of linear expansion of glass, and is therefore inappreciable. For use in mountaineering, Mr. Davis substitutes a number of glass vessels communicating by means of stop-cocks, for the single glass vessel at the end of the tube in Figs. 5 and 6. For a given range of d, it is obvious that a smaller value of V is required for low than

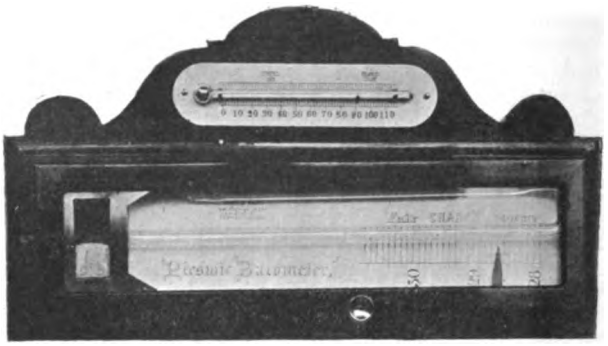

FIG. 7.—THE "PIESMIC" BAROMETER.

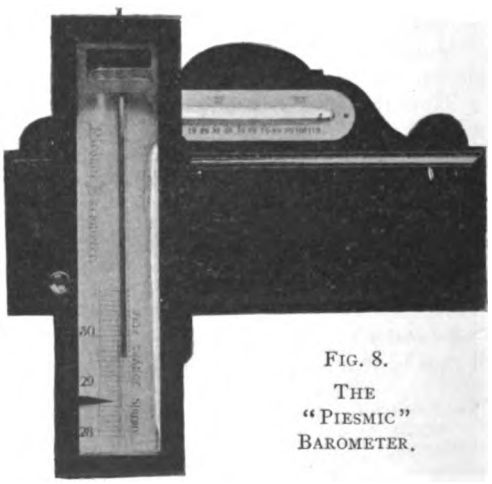

FIG. 8. THE "PIESMIC" BAROMETER.

for high pressures; this can be ensured by cutting off part of the original volume V by closing the necessary stop-cocks. Figs. 7 and 8 represent the barometer as made by Messrs. F. Darton & Co., 142, St. John's Street, E.C.

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The Frequency Changer

THE frequency changer (Fig. 9), as its name denotes, is a machine or series of machines for altering the periodicity of an alternating current circuit. It consists of the following, rigidly coupled together: a synchronous motor designed for the frequency of the supply circuit, an alternator with a greater or less number of poles than the former, according to whether the periodicity is to be raised or lowered, and an exciter for energising the fields of both machines, and also for the purpose of running the set up to speed and synchronising.

For obvious reasons frequency changers are not much in use, but occasions do arise where it is necessary to raise or lower the periodicity of part of the output of a supply station; and to save the inconvenience of extra steam-driven sets, and also the reduction of the plant load factor that such a method would bring about, the frequency changer is installed.

Being simply an ordinary motor-transformer with its own exciter, there is nothing particularly interesting about it as a machine, but the operation of two frequency changers in parallel is attended with some variation from ordinary alternating practice, and is well worth investigation. Presuming one of these machines to be fully loaded, and that it is desired to parallel another with it to take up part of the work, the incoming machine will be started by the exciter, run up to speed, and synchronised in the usual way by varying the field resistance of the motor for the time being, otherwise the exciter. The alternating motor side of the set is now paralleled, and the exciter takes up its proper function. If the ordinary methods of paralleling alternators were now followed, the volts of the incoming generator would be made equal to that of the loaded machine and the switches closed; and the load would be adjusted by speeding up the second prime mover, and at the same time raising the volts of the alternator. But with a frequency changer, since it is driven by a synchronous motor, an increase of speed relative to that of the loaded set is an impossibility, both being in parallel. Also, it is a commonly known fact that varying the respective voltages when two alternators are electrically coupled is of no avail in shifting the load, and simply results in useless cross currents between the two. Hence, if the generators are paralleled in the ordinary way at equal voltage, it is impossible to get the second one to pick up any load, as the speed cannot be raised, and variation of its voltage does no good. It is, therefore, necessary to proceed along different lines as follows: The excitation of an alternator must be raised with the load, and at any given value of the load the exciting current will have a certain value; therefore, if the generators of the two frequency changers are of the same type and size they will require the same amount of exciting current at equal loads. It has been found that if they are paralleled in this condition, that is, with equal exciting current and, consequently, a very much higher voltage on the incoming machine, due to its being unloaded and therefore having no drop in its armature, they will divide the load equally between them, or in a proportion that will vary with the relative values of the exciting currents.

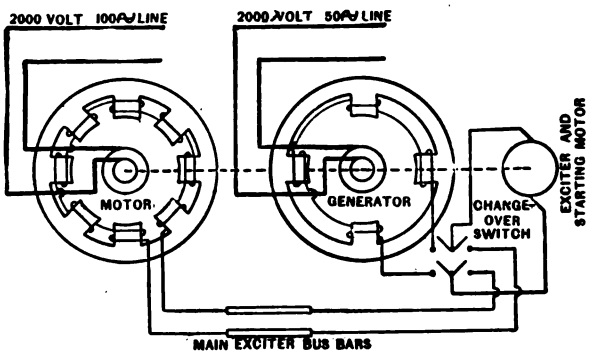

FIG. 9.—A FREQUENCY CHANGER.

A little thought will make the reason of this action obvious, it being remembered that at the moment of paralleling there is a wide difference of pressure between the machines, which must result in the second one instantaneously appropriating some of the load. If this difference of pressure is made *after* the paralleling of the generators, it is neutralised as fast as it is made by the reaction on the field system of the wattless current that it will produce in the armature. The changing over of the load is necessarily very sudden, but as the machines are purely rotary it is not accompanied by much shock or jar.

Motor Car Brakes

INTERNAL expanding brakes are now frequently met with on motor cars. They are conveniently fitted inside the chain sprockets on the road wheels of those of the chain-driven type. A metal-to-metal brake is far ahead of the old leather or wood-lined single-

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acting band brake, being more easily applied and far more certain in its action. We seldom hear now of accidents due to brake failure. Fig. 10 shows the type of internal brake fitted to the "Mercedes" cars, built by the Daimler Motoren Gesellschaft of Cannstadt. It is of the toggle type, and has the "side" or "emergency" brake, operated by a lever at the side of the driver. The shoes are hinged and are expanded into the chain ring by toggles actuated by a double lever carried on the chain radius rod. The resisting effort of the brake is transmitted to the frame by the radius rod, as it also carries the pin on which the shoes are hinged. To resist this stress, the radius rods have to be

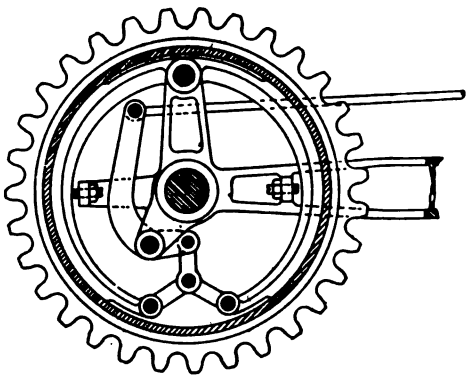

FIG. 10.—INTERNAL BRAKE FITTED TO "MERCEDES" CAR.

made strong, considered as beams, and are usually of I-section. The "Wolseley" car is also fitted with an expanding metal-to-metal brake, but in this instance it is operated by a pedal, the "side" brake being a double-acting band brake. The levers of this brake are so arranged that, though acting in both directions, the brake is more powerful when the car is travelling forwards than backwards, and the radius rod transmits the resistance to the frame, as in the "Mercedes" brake. The brake drums are carried by the sprockets on the road wheels, and it is a point worthy of notice that both brakes on this make of car are on the road wheels, so that the brake power is independent of the chains, and is, therefore, not affected should one break. The braking effort is transmitted through the radius rods instead of through the chains, as in the case of countershaft brakes, thus lengthening their life, as, naturally, the stress caused by the application of a powerful brake is much greater than the drive from the engine. On all up-to-date cars the brakes are so powerful that the driver can lock the wheels and cause them to skid on the ground; but the maximum braking effort is found to be attained just before the wheels commence to skid, and not when they are actually locked and slide on the ground.

A Rapid Kinematograph

(By our Berlin Correspondent)

AN interesting kinematographic device for taking photographs of moving objects at enormously high rates has been designed by Mr. Lucien Bull, of Paris, who avails himself of the exceedingly short duration of the electric spark. As this may be estimated at about 1/2,000,000 part of a second, a moving film will traverse a distance quite inappreciable during this small interval of time, so that an image produced by the aid of the spark may be as sharp as on a fixed film. In order to obtain a series of images at constant distances, so as to be able to effect the synthesis of the various snapshots, Mr. Bull produces the electric sparks at intervals corresponding to equal displacements of the film, using for this purpose the outfit shown in Fig. 12. In a casing A is placed a cylinder B, which is mounted on a horizontal axle. To the same axle is fitted, outside the casing, a rotary

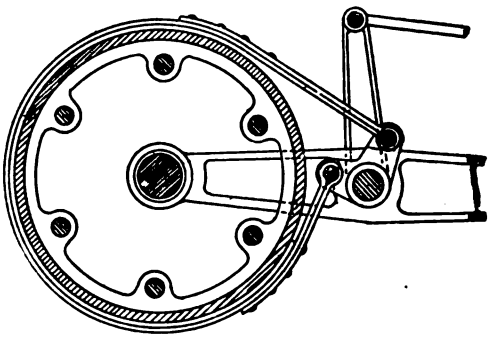

FIG. 11.—DOUBLE-ACTING BAND BRAKE, FITTED TO "WOLSELEY" CAR.

current interrupter, serving to break the primary circuit of an induction coil D at a given frequency during each revolution of the cylinder. A condenser F is connected in parallel with the secondary circuit connections, the spark jumping in E between two magnesium electrodes behind the lens G, which concentrates the rays on the objective O, in the focus of which the cylinder turns. The cylinder bears a sensitised film and rotates rapidly. At each revolution a number of sparks corresponding to the number of contacts on the interrupter passes at E; the objective has only to be opened during one

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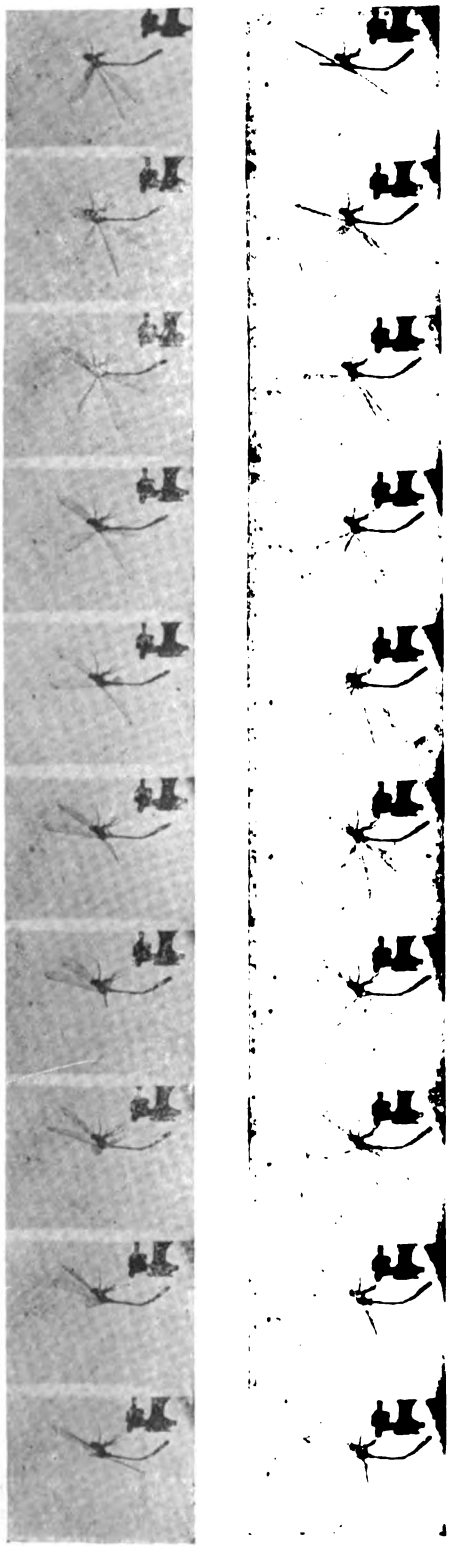

revolution, to obtain a series of images of an object placed between the lens G and the objective at constant distances apart. This is effected by a double shutter, which is opened at the given moment by the passage of a cam fitted on the edge of the cylinder, while the closure of the objective occurs automatically at the subsequent revolution under the action of the same cam. The accompanying series of views shows a

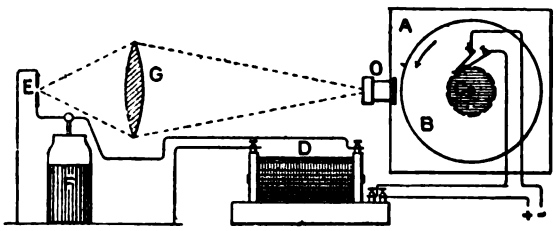

FIG. 12.—BULL'S KINEMATOGRAPH.

dragon-fly (*Agrion puella*) starting on its flight. The highest speed so far obtained is more than 2,000 views per second, but this figure will no doubt be exceeded by means of specially constructed outfits for the production of the electric spark.

Modification of the Patent Laws

IN the past, applicants for patents in the United Kingdom have been obliged to make a search amongst the records of previous patents, if they wished to know whether their invention had been anticipated or not. With the commencement of the year 1905 the new law comes into force, by which the officials of the Patent Office are required to institute a fifty-year search among existing patents, and to inform the applicant as to the nature of those already obtained which are on similar lines to that applied for. To provide for the extra work thus entailed, the staff of the Patent Office has been largely augmented, extra examiners having been selected by competitive examination. There is no doubt that the facilities thus afforded to inventors will prove of the greatest importance in fostering technical progress, as in the past much money has been spent in patenting similar devices over and over again.

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BALLISTICS OF MODERN RIFLES.

By R. H. HOUSMAN, B.Sc., M.I.E.E.

SINCE the great improvements due to the introduction of smokeless powder and cupro-nickel or steel envelopes for bullets, the ballistics of military rifles have undergone comparatively little change.

The tendency towards extremely small bores for military purposes seems to have been checked by the failure of the American Navy pattern rifle of ·236 bore. The smallest bore which has met with success is the ·256 Mannlicher. There now seems to be a tendency in favour of somewhat larger bores, as instanced by Germany's retention of the 7·9 mm., and America's adoption of a ·300 bore for both services. Hitherto, the one bar to improved ballistics with rifles of this bore, has been the increased weight and bulk of the cartridge, and the increased recoil which is the result of increased velocity. With a larger bore, there is no trouble in getting the same striking energy as with the ·256 Mannlicher, but a velocity of 2400 feet per second is only obtained at the expense of increased recoil, and heavier cartridges; the immense advantage of flat trajectory, however, demands that no effort should be spared in overcoming these difficulties.

It can hardly be denied that progress with other forms of explosion engine is largely due to the knowledge of the processes going on inside the cylinder, which we have gained from the use of the indicator. For instance, the design of petrol motors will undoubtedly profit largely from the work of Professor Callender in designing an indicator suitable for speeds of over 2000 revolutions per minute.

The design of rifle and cartridge has, up to the present, been largely on empirical lines, and too little use has been made of the means at our disposal for taking diagrams which will indicate the exact nature of the changes of pressure in the barrel, and the modification caused by variation of charge, volume of chamber, form of explosive, etc.; and until the subject is dealt with on engineering lines, there seems little chance of rapid improvement, although the slow and expensive processes of trial and error would, no doubt, secure good results in the long run.

The subject of internal ballistics appears to be much in the same state as was that of external ballistics before the classical investigations of Bashforth. A good deal of work has been done, but we have much more to do before our knowledge of the subject can be considered to be satisfactory.

An account is given below of some of the conclusions arrived at from investigations carried out at the works of Kynoch, Limited, near Birmingham.

Internal Ballistics.

The difficulties of recording the rise and fall of pressure in the bore of a rifle are vastly greater than in the case of any other explosion engine. The time of a working stroke is about $\frac{1}{100}$ of that of an ordinary gas engine, and the pressures are about one hundred times as high. Errors due to the inertia of any indicating apparatus have therefore to be most carefully guarded against, and this constitutes one of the greatest experimental difficulties.

The means employed by the writer for the purpose of determining the pressure acting on the bullet as it passes up the bore, consist of a series of eight crusher gauges (Fig. 1) placed at intervals of three inches along the barrel, the first one being connected with the chamber, and the second with the bore three inches in front of the base of the bullet before firing. The last gauge is five inches from the muzzle, the length of barrel being twenty-eight inches (Fig. 3).

Each crusher gauge consists of a small steel piston, working in a carefully fitted cylinder, which is screwed into the barrel and connected with the bore by a small hole, the size and shape of which is adjusted until the piston is nearly dead-beat. The whole of the space

Fig. 1.
Cylinder and Piston of Crusher Gauge.

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between the piston and the bore is filled with cylinder oil, which is renewed every third shot. On top of the piston is placed a copper cylinder $\frac{1}{4}$ in. long $\times$ $\frac{1}{8}$ in. diameter, made from high conductivity copper wire, and annealed at a certain temperature, so that all strains are relieved. The object of using so small a cylinder is to reduce the time lag as much as possible. The copper cylinder or crusher is held in place by a screw which presses it firmly on to the piston. The pressure is determined by measuring the length of the crusher after it has been compressed by the gases in the barrel acting on the piston. A table of pressures corresponding to various lengths is constructed by firing a progressive series of charges in a gun having three pistons acted on simultaneously by the gas pressure.

The areas of these pistons are in the ratios 1·0, 1·25, and 2·0; these give the crusher lengths corresponding to pressures in the same ratios. In this way the form of the curve connecting pressure and length of crusher is determined, and the actual values are given by dead weight experiments with pressures which do not cause any appreciable flow of the copper after the first instant. The curve then holds good for all values up to that given by the largest charge on the largest piston used in the experiments. If dead weights alone are used, the curve is incorrect for pressures above about 13 tons per square inch of copper section, at which point time-flow commences.

The adjustment of the holes leading from the barrel to the cylinder is somewhat tedious, but is most important. It the hole is too small the time lag is excessive, and is difficult to estimate; whilst if it is too large, the piston over-shoots too much, and the measurements are untrustworthy.

The best results are given when there is an over-shoot of about 10 per cent. which can be allowed for.

The time lag is then about 25 per cent. greater than with an undamped piston. The pistons used vary from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. diameter, the last six having areas approximately inversely as the pressures exerted on them under average conditions. This practically eliminates any question of error in the crusher table.

The weights of the pistons vary from eleven to thirty-three grains, and the crushers weigh seven grains each.

The time lag of the lightest piston (undamped) is ·000072 seconds, or ·00009 seconds damped. The times are proportional to

$$\sqrt{\text{Wt. of piston} + (1/3)\,\text{Wt. of crusher}},$$

so that the heaviest piston has a time lag of 0·000156 second. With a velocity of 2000 ft. a second the bullet moves nearly four inches whilst the crusher is registering, so that the last piston, which is five inches from the end, gives the pressure when the bullet is about one inch from the muzzle.

Fig. 2 shows the corrected and uncorrected pressure diagrams for the Service ·303 cartridge with thirty grains cordite fired in a rifle with a "short lead," which gives higher pressures than the service rifle. Although the difference of area in the two diagrams is considerable, the general characteristics are the same, so that when only a comparison of the behaviour of different forms of cordite is required, the uncorrected diagram is sufficient to indicate the difference. The corrected diagrams are required for determining the percentage of energy absorbed by friction, or for finding the law of expansion of the gases.

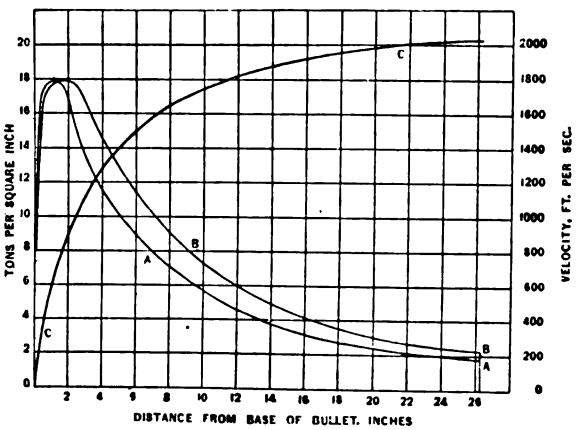

FIG. 2.—PRESSURE AND VELOCITY CURVES OF ·303 "SHORT LEAD" RIFLE, WITH 30 GRAINS CORDITE AND 215 GRAINS BULLET.

A, A—*Uncorrected pressure curve.* B, B—*Pressure curve corrected for time lag.* C, C—*Velocity curve.*

The pressure gun is suspended by steel wires about four feet long, as shown in Fig. 3. By this means recoil is measured at the same time as pressure, and velocity records are also taken by means of the well-known Boulanger chronograph. The various pressure curves shown are all obtained from this instrument. Before discussing the results a sketch of the theory which has been found consistent with these experiments is necessary.

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The most important point, *viz* :—the law connecting rate of combustion of cordite and pressure, can only be inferred, since its direct determination involves measurements of time intervals of the order of one millionth of a second. This remains to be done. In the meantime indirect evidence seems to point to a nearly direct proportionality between pressure and rate of combustion. Assuming this law, and that for a short time the net volume of the chamber and the temperature are constant, it can be shown that the rate of increase of pressure is equal to the product of the pressure multiplied by the volume of gas evolved per second (measured at the pressure under which it is evolved), and divided by the net volume of the chamber. This expressed mathematically is

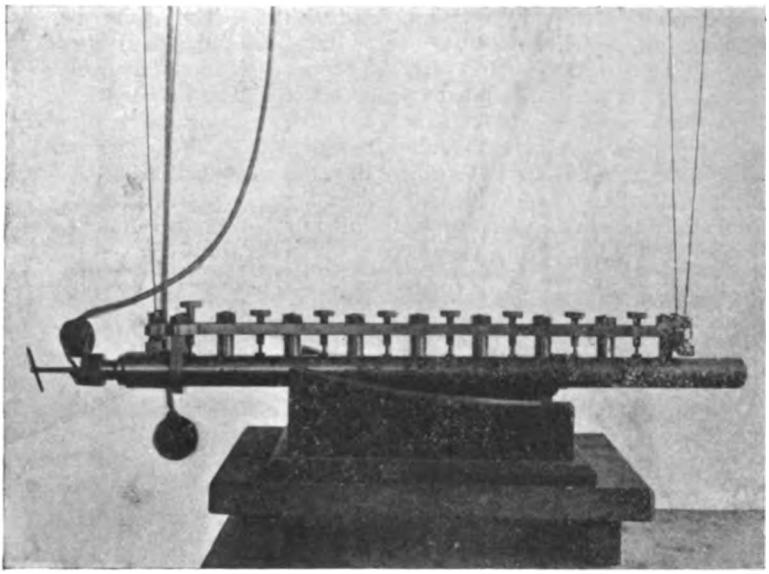

FIG. 3.—PRESSURE GUN WITH EIGHT GAUGES, SUSPENDED FOR MEASURING RECOIL.

$$\frac{d\,p}{d\,t} = a\,p,$$

where

$$a = \frac{\text{the area of burning surface}}{\text{net volume of chamber}} \times \text{mass of}$$

gas evolved per second per unit surface; and since a is constant, the volume of gas evolved per second, measured at the pressure under which it is evolved, is constant at all pressures.

Hence,

$p = p_o e^{at}$ where p_o is the pressure when $t = o$.

For any two pressures, $\log_e \frac{p_2}{p_1} = a\,(t_2 - t_1)$.

If p_1 is the initial pressure produced by the cap, then $\log_e \frac{p_2}{p_1} = a\,t$, where t is the time which has elapsed since $p = p_1$.

Thus, for

$$a\,t = 1, \frac{p_2}{p_1} = 2{\cdot}72,$$

and for

$$a\,t = 2{\cdot}30, \frac{p_2}{p_1} = 10.$$

$\frac{1}{a}$ may be called the time constant of the explosion curve, being the time in which the pressure increases to $2{\cdot}72$ times its original value, and $\frac{2{\cdot}30}{a}$ is the time in which the pressure increases tenfold.

The time constant $\frac{1}{a}$ is proportional directly to the net volume and inversely as the burning surface for a given explosive.

It has been assumed above that a is constant, but this is not generally the case. Take, for example, the usual strand cordite; here the diameter of the strands, and consequently the surface, diminishes as combustion proceeds. Under constant pressure the surface would be reduced at a constant rate, and the average would only be one-half of the initial value. Under similar conditions with spherical grains the average would only be one-third of the initial surface, whilst with a large thin sheet the initial, average, and final surfaces would be practically equal. The best possible form would be a cylinder with a small central hole, and the ends and outside surface protected against combustion. This would give a uniformly increasing rate of evolution of gas which would compensate for the increase of volume due to the acceleration of the bullet, and so tend to produce a uniform pressure whilst the combustion lasted. This ideal has not yet been attained.

The American military powder consists of short cylinders, the diameter of which is 75

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per cent. of the length, pierced by an axial hole about one-third of the outer diameter. The final surface is 32 per cent., and the average 66 per cent. of the initial surface.

The form most commonly used on the Continent is a square flake with a thickness about 15 per cent. of the side of the square. This gives a final surface of 46 per cent., and an average of 73 per cent.

The form recently adopted by Kynoch, Limited, is a flat strip with a thickness of about 15 per cent. of the width of the strip. This gives a final surface value of 74 per cent., and an average of 87 per cent.

These figures are summarised below :—

Form.	Ratio of average to initial surface.	Ratio of final to initial surface.
Spherical	33%	0
Round strand	50%	0
Short hollow cylinders . . .	66%	32%
Flake thickness, 15%	73%	46%
Fat-strip thickness, 15% . . .	87%	74%
Wide thin sheet	100%	100%

The great advantage of a form having a high final value is that it makes possible the complete combustion of the explosive at a comparatively early stage, without involving such a large initial surface as to unduly increase the maximum pressure. In the Service ·303 rifle, strands of unburnt cordite a few thousandths of an inch thick are blown from the muzzle. This can be avoided by using either thinner strands or flat strip. The former increases the pressure considerably, the latter reduces it, as will be shown later.

Returning now to the consideration of the rise of pressure when a cartridge is fired, we may consider the initial pressure as determined either by the pressure produced by the cap, or that which is required to start the bullet from the case, whichever happens to be the highest. A value of one ton per square inch may be taken without serious error. It will be seen from the equation for the rate of rise of pressure that the time in which the pressure would increase tenfold if the bullet did not move, and the surface remained constant, is $\frac{2 \cdot 3}{a}$. If the bullet is free to move, the time of reaching a tenfold pressure is prolonged, and will depend not only on the burning surface and volume of the chamber, but on the weight and diameter of the bullet.

Thus, the rate of rise of pressure in the earlier stages depends entirely on the value of a, or for a given explosive on the value of

$$\frac{\text{area of burning surface}}{\text{net volume of chamber}}$$

provided always that the initial pressure is the same; yet, when the pressure arrives at its maximum value, the velocity of the bullet depends upon this value of

$$\frac{\text{area of burning surface}}{(\text{diameter of bore})^2}.$$

This will be clearly seen by considering that at the instant of maximum pressure the rate at which the volume of the chamber is increased by the motion of the bullet is equal to the rate at which the volume of the gases is increased by the combustion of the explosive. The latter quantity for a given explosive, by our preliminary hypothesis, depends only on the burning surface, and is the same for all pressures. Thus if V_{mp} is the velocity of the bullet at the instant of maximum pressure, and d the diameter of the bore, or

$$V_{mp} d^2 \propto \text{burning surface}$$

$$V_{mp} \propto \frac{\text{burning surface}}{d^2}$$

V_{mp} may be called the critical velocity, and is independent of weight of bullet or volume of chamber, so long as the burning surface remains the same. The measurement of the critical velocity enables us to estimate the rate of burning at various pressures. If w be the weight of the bullet, then $\frac{V_{mp} w}{g}$ = area of time-pressure diagram up to point of maximum pressure *minus* the area of the time-friction diagram up to the same point.

Also $\frac{w V^2_{mp}}{2g}$ = area of space-pressure diagram up to maximum pressure-friction diagram. This calculation from Fig. 2 gives the approximate value of V_{mp} as about 900 ft./secs. for the Service rifle, which agrees very well with an experiment with a barrel cut down so that the travel of the bullet was about two inches, which corresponds to the point of maximum pressure.

The time-pressure curve may be calculated by assuming a constant for a short interval of time such as $\frac{1}{1000}$ second, and making suitable corrections at each interval for the altered conditions of surface and volume. The process is tedious, but gives results sufficiently agreeing with observation to justify the assumptions made.

The effect of increasing the initial pressure by using a stronger cap, or fastening the

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bullet more firmly in the case, is to increase the rise of pressure in a given interval of time in the same proportion, so long as a remains nearly constant; but the higher pressure causes a more rapid acceleration of the bullet, and a more rapid reduction of the value of a: the maximum pressures are therefore not proportional to the initial pressure, although they show a marked increase as the initial pressure is raised.

The distance travelled by the bullet before entering the rifling has a very considerable effect on the maximum pressure. For example, if the "free travel" of the bullet of a ·303 rifle be reduced from ·5 in. to ·2 in., the pressure rises from 16 tons to 18 tons. This is accounted for by the retarding of the bullet owing to the great pressure, amounting to some tons per square inch, required to force the bullet into the rifling. This increases the time required to give the critical velocity, and during the extra time the pressure continues to rise. If there is no free travel, the initial pressure must be reckoned as that required to force the bullet into the rifling; since this may amount to several tons per square inch the initial rise of pressure will be very rapid, and the maximum pressure consequently very high.

On various occasions the term "net volume" has been used above; this may be defined as the total volume *minus* the volume occupied by any solid substance. The explosive is included as a solid substance, and its solid volume is supposed to remain the same after explosion. This can be justified theoretically, but an experiment devised to settle the point, which will be described later, is the real basis for the assumption. The tables based on Sir A. Noble's experiments, which appear in the Service text-books, also support this view. In these tables the volume of the gases from a given quantity of cordite, at various pressures, is given; the product of these values of p and v increases considerably with the pressures, showing that pv is not constant. If, however, the volume of the cordite is subtracted from that of the gases, the product of this net volume and the pressure is nearly constant from 10 to 30 tons per square inch.

We shall now consider the form of diagram which is most desirable, and compare it with those actually obtained. It is often stated that the best form of diagram for a rifle is that which shows uniform pressure from breech to muzzle; this, however, would be as undesirable in a rifle as in a steam engine. As a matter of fact, the ideal diagrams in the two cases are very similar, but the actual rifle diagrams more nearly resemble those of a gas engine. The points to be aimed at in a rifle diagram may be stated as follows:—First, the combustion of the propellant as much as possible at the maximum pressure, which should consequently be nearly constant during the combustion of the explosive; and second, the subsequent expansion of the gases down to a pressure not exceeding about three tons. The first condition is never approached with any existing propellant, since at least one-half is spent in reaching the maximum pressure, and in many cases combustion is not complete when the bullet leaves the barrel. It need hardly be said that all the explosive that burns near the muzzle is practically thrown away, and only serves to heat the barrel and increase the recoil. A low muzzle pressure is desirable, to cool the gases and reduce the blast which is liable to disturb the steadiness of the projectile; it also tends to reduce recoil. The great bar to the attainment of these two conditions is the excessive chamber capacity which is necessary to keep the maximum pressure within limits when the initial surface of the explosive is much greater than the average surface.

(*To be continued.*)

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THE SAFETY OF SUBMARINES.

By ALAN H. BURGOYNE, F.R.G.S., Author of "Submarine Navigation, Past and Present," "The Future of the Submarine," etc., etc.

FIG. 1.—INTERIOR OF THE "HOLLAND."

From "The Romance of Modern Invention," by Archibald Williams. By permission of C. Arthur Pearson, Limited.

NO type of vessel has been the subject of more public attention than the submarine boat. Certainly, during the last three or four years in England, and since 1888 in France, this novel and untried weapon of modern warfare has been kept continuously before the public; and, if we may judge by the contemporary press, it would be hard to say what things these craft are incapable of doing.

Some are to conquer the frozen North, and put Nansen and his compeers to perpetual shame; others will rush across the Atlantic at speeds that would allow the *Kaiser Wilhelm II.* three days' start; whilst many more, on their launch (or even projection), have been held to have doomed the battleship and cruiser to summary destruction. But, in all cases, writers have obviously forgotten the limitations of a type of craft which, though already experimented on for many years, is still in its infancy. Our present submarines are little more than expensive toys, and their development into efficient units of the modern battle-fleet will occupy years of ceaseless trials and experiment. Thus far we have got, however: they can dive in absolute safety, how, when, and where their commander desires; their stability is practically perfect; and their ability to cruise in the open sea has been demonstrated on more than one occasion. As to their

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limitations, they possess very poor speed, a meagre armament, and no methods of safety for the crew should an accident occur.

In most submersible vessels, nominal security is obtained by the possession of a reserve of buoyancy sufficient, should all bear in mind that our British submarines are not the only ones in existence. There is a tendency in certain quarters to regard the *Holland* and *A1* types as the "be all" and "end all" of the submarine question; but to endeavour to apply special apparatus

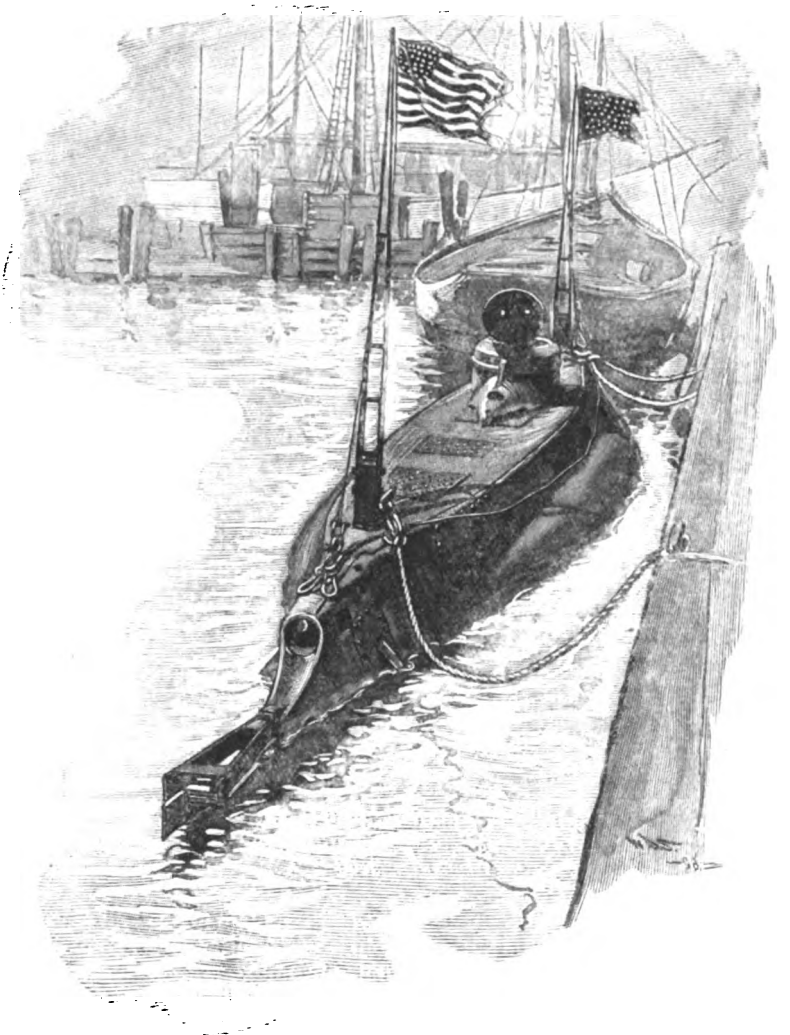

FIG. 2.—THE "HOLLAND" SUBMERSIBLE BOAT.

From "The Romance of Modern Invention," by Archibald Williams. By permission of C. Arthur Pearson, Limited.

other machinery break down, to bring the boat to the surface. This is an obvious method, and needs little comment; but its value is not great in the case of a collision such as that which caused the loss of the *A1*. Before proceeding to a detailed discussion of the various methods of securing safety in submersible craft, I would ask my readers to to little experimental boats that have scarcely sufficient space for their propulsive mechanism is obviously absurd. The new French submarines of the *Emeraude* class are of 422 tons displacement, and I am in a position to state that no such accident as that which cost the lives of the gallant crew of the *A1* would endanger those of

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the crews of these latest creations of our Gallic neighbours.

Yet something might be done even with the small *Holland* boats of 120 tons displacement, or the somewhat heavier *A1-A9* class. Let us consider for a moment the position of the men in a vessel of this type in the event of an accident. In a small space about sixty feet in length, with a varying diameter of from 10 feet to about 1 foot 6 inches, are cooped up five to eight human beings. At a given signal, the only method of egress is hermetically sealed, and the boat driven below the surface; it is now in the position of a steel coffin containing eight live men. Suddenly a shock is felt, and a spurt of water rushes in through a small breach in the plates. What must the occupants do? Now there are two points of view from which to approach this question, and each rests on a supposition. The first takes for granted that, as the immediate result of the concussion, the whole of the living occupants are rendered unconscious or incapable of action; the second pre-supposes that some or all of the crew retain their senses, and are in a position to do everything possible for their salvation.

Far more importance attaches to these two points than might be supposed; for, in the first eventuality, no device actuated by hand power would be of the slightest avail. Captain Bacon, the well-known British authority on the *Holland* type of submarine, stated in his evidence at the enquiry into the causes of the *A1* disaster, that in his opinion the whole of the crew of the *A1* were, if not killed, at least rendered unconscious as the result of the collision with the *Berwick Castle*. Yet, although he holds this view, in his criticism of a paper I recently had the honour of reading at the Royal United Service Institution, he depreciated in no mild terms my proposals for automatic safety appliances in submarine boats, preferring rather to rely on the intelligence of the crew than to trust to automatic mechanical devices. Whilst everyone will, I feel sure, give due weight to Captain Bacon's opinion, it must, nevertheless, be obvious, even to the uninitiated, that manually-operated machines could scarcely render the services for which they were designed when those intended to operate them are deprived of their senses.

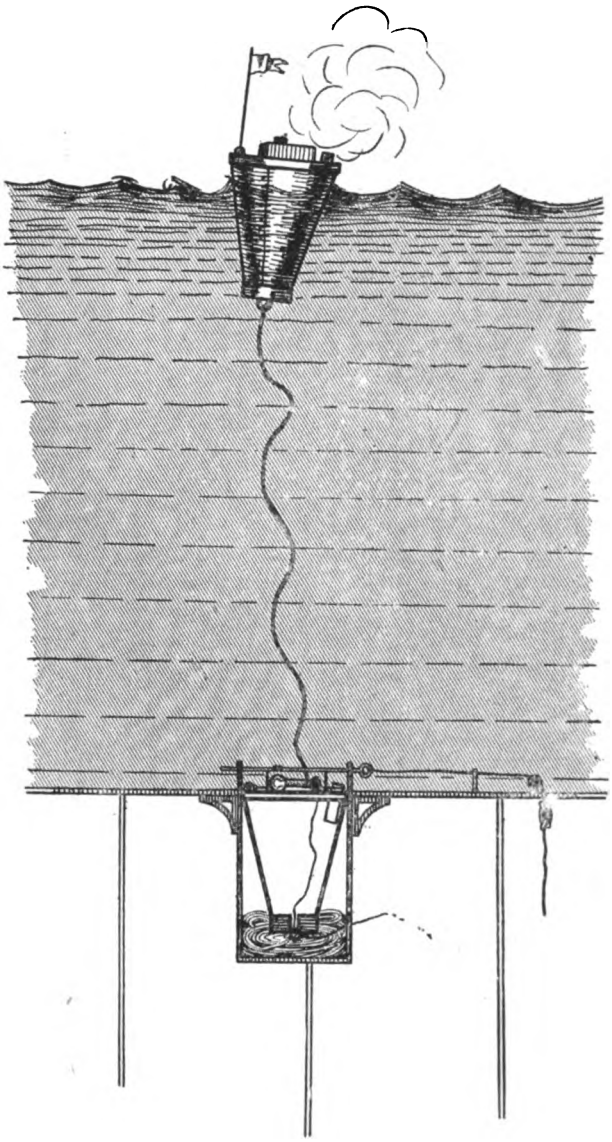

FIG. 3.—A DETACHABLE SAFETY BUOY.

For this reason I am inclined to favour as many practical automatic appliances as possible; and it seems difficult to account for the recent contradictory views of Captain Bacon, when compared with his beliefs given in the evidence on the recent disaster off the Nab Light. Take first the most simple idea applicable to almost any submarine of whatever size. This is an appliance which I call "the detachable safety buoy," and its principle

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is clearly shown by a glance at the appended sketch (Fig. 3). In the event of a submarine becoming entangled by an obstruction at the sea-bottom, or unable to rise for some reason, the commander possesses no means of informing his friends above of his predicament. If, now, a safety buoy such as I shall describe be provided, he would at least be able to open up communication with those above. The apparatus consists of a small steel buoy fitted on its upper face with a water-tight box; this box contains the one terminal of a metaphone, and is telephonically connected, by means of a wire, with the interior of the submarine. In large submersibles this buoy might be fitted flush with the deck in a recess built in the hull itself; in our *Holland* type it could conveniently be placed just aft of the conning tower, in a steel box placed on the light superstructure. It would be retained in its position by a light steel rod capable of release from within. It might further be fitted with a small signal mast about two feet in length, bearing a certain distinguishing flag, and a Holmes light; if, with these aids, a submarine placed in the awkward predicament I refer to were not speedily located, it would say little for the energy of the searchers.

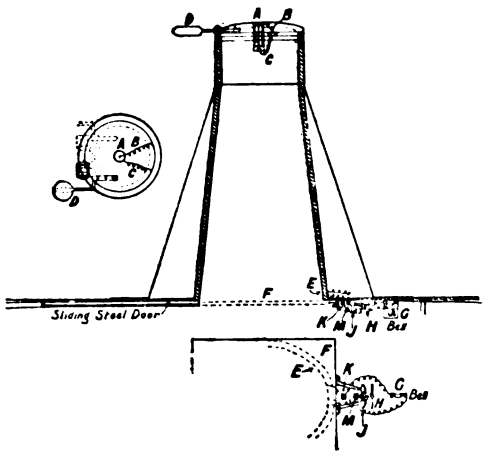

FIG. 4.—MECHANISM OF WATERTIGHT DOOR FOR ISOLATING CONNING TOWER.

We next come to the question of the conning tower. This must, in every case, project some distance above the deck line of the hull, and hence, when submerged, must prove a source of danger, as the accident to the *A1* has recently shown. When below the surface the conning tower is useless, since all operations connected with navigation could very well be carried on within the hull proper of the submarine. This being the case, a horizontal steel door might be fitted level with the deck; on reaching the depth at which the lid of the submarine became immersed, this automatically shuts off the conning tower from the interior, thus, in case of a leak, preventing a rush of water into the hull.

In considering this proposition, I would again especially ask my readers to banish the *Holland* type from their minds. I have made a careful and systematic study of this class (thanks to the great courtesy of the "Holland Torpedo Boat Company," of New York), and grasp fully the fact that in the units already constructed from these designs, many very serious difficulties would be experienced in the application of a sliding door such as I propose. But in future designs, it should receive serious consideration, for no less an authority than Sir Edward Reed, K.C.B., has given me his opinion that, by a careful study of this feature, many of the present dangers might be combatted. Should the "automatic closing" not appeal to service men (and, after all, their opinions are the first to receive consideration), a simple expedient could be devised whereby the officer in charge would be reminded of his duty to close the sliding door.

In the lid of the conning tower should be fixed a hydrostatic valve, or disc, connected to an ordinary bell-push by a slight spiral spring; this disc externally has the pressure of water acting on it, and the moment the conning tower becomes submerged, the disc would be compressed and in turn act on the spring, thus completing a circuit. The bell (to which the bell-push would be connected in the ordinary way) would commence ringing, and continue doing so until the shutting of the sliding door cut off the current. The appended sketch (Fig. 4) shows roughly what I mean.

In the event of the swing of the conning-tower lid interfering with the electric connections, these might be made direct through the metal of the toggle locking device employed for closing it. Any other method might conceivably interfere with the water-tight condition of the lid, which in the *Holland* and most French boats is secured by compression against a rubber gasket.

There is one further device applicable to vessels of the *Holland* type, or indeed to almost any of the smaller classes of submersible craft. This takes the form of one or more heavy metal drop-weights, fixed in such a position beneath the keel, that their sudden release will not appreciably affect the longitudinal trim of the boat. This device

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FIG. 5.—SECTION OF "GYMNÔTE," SHOWING DETACHABLE SAFETY WEIGHT.

is a very favourite one in both France and Russia, and has also been employed in Italy. The weights should be divided into one or more even blocks, each of which becomes detached in turn after a quarter-rotation of a releasing lever. To illustrate the application of these weights, I append two elevation diagrams (Figs. 5 and 6). The first of these represents the French *Gymnôte* designed by M. Gustave Zédé, and the second the *Porpoise*, a small submarine launched in 1886 at Seacombe, and built to the designs of Mr. Waddington.

Our submarines are open from end to end, and hence a single breach fills the whole vessel. As these craft increase in size, a system of sub-divisions should, and no doubt will, be introduced. Each vessel should be sub-divided into seven or eight separate compartments, communication between these being obtained by automatic water-tight doors, such as are to be found in all modern surface-warships and the majority of passenger vessels. One or all of these compartments should be capable of isolation, by automatic closing apparatus, from any individual compartment. I have been told that the hygiene of the crew requires to be considered before sub-dividing a submarine; but I would have it borne in mind that such sub-divisions would be ridiculous in any vessel under 200, or at the least 150, tons, and could not, indeed, be fully applied to any submersible having a lesser submerged displacement than 400 tons. The French *Emeraude* vessels have been divisioned off into a number of compartments, but not in the complete way I propose, in which the divisions would extend from top to bottom of the hull and from side to side, the only means of communication between each being the water-tight doors above referred to. A vessel fitted as I describe could, if the designs emanated from a practical naval architect, be rendered immune from disaster in the event of only one compartment filling; and if this fact were known to a crew, they would undoubtedly give infinitely less consideration to their risk of destruction in an attack, than they would if they knew that the first breach in the hull meant certain death.

As submarines grow larger, so will the total of weight allotted to safety appliances increase in amount; and in vessels from 400 tons upwards it should not be found a very difficult matter to make an addition of one or more detachable safety boats, capable of holding the entire crew, and possessing sufficient buoyancy to rise, when detached, to the surface. These should, in the case of a vessel subdivided in the manner I have just described, be fitted with hatches in two or more compartments, to add further to the chances of escape for the crew. Such a boat was first designed, and indeed experimented with, by MM. Bourgois and Brun, in their 453-ton submarine, the *Plongeur*, launched at Rochefort on April 16th, 1863. On September 15th of the same year, the *Plongeur* proceeded to sea to test the efficacy of the detachable life-boat. The trial was quite successful, the little boat, with half a dozen occupants, leaping off the parent-ship the moment the screws were loosed.

Twenty-four years later, in 1887, Lieut. G. W. Hovgaard, of the Royal Danish Navy, published the plans of a submersible torpedo-boat, which was to displace no less than 740 tons. One of his special features is a detachable boat, which he describes as follows:—

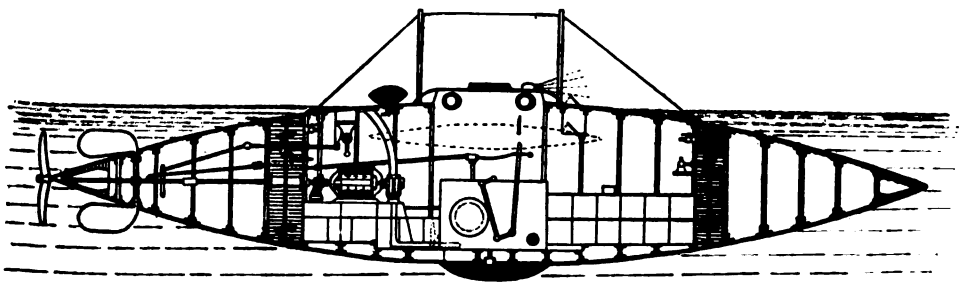

FIG. 6.—THE "PORPOISE"; FITTED WITH DETACHABLE SAFETY WEIGHT.

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"If, in spite of all precautions, the ship should sink to the bottom, without being able to get up again by its own means, as might happen by a breakdown of the motors or pumps, or in the case of a great leakage, it must be possible for the crew to escape. This is the reason why a detachable boat ought to be fitted. In the present design it has been placed in the top of the ship, in a hollow built down into the superstructure (Fig. 7). The superstructure extends for a length of 32 feet, and has a height above the top of the ship of 2 feet 3 inches. Thereby we gain head-room underneath the boat in the steering room. The detachable boat is designed to stand the same pressures as the boat will ascend to the surface. Communication with the vessel, if somebody should be left behind, may be kept up by telephonic connections.

"When the boat comes to the surface, the doors in the upper part are opened. This boat is essentially the same as that in *Le Plongeur*."

The appended plan (Fig. 7) gives a very good idea of Lieutenant Hovgaard's invention. In a recent design of my own, I followed out the idea of Hovgaard, and Bourgois and Brun, with slight modifications.

One last proposal which applies to all submarines, though particularly to those of small or medium size. This is, that all

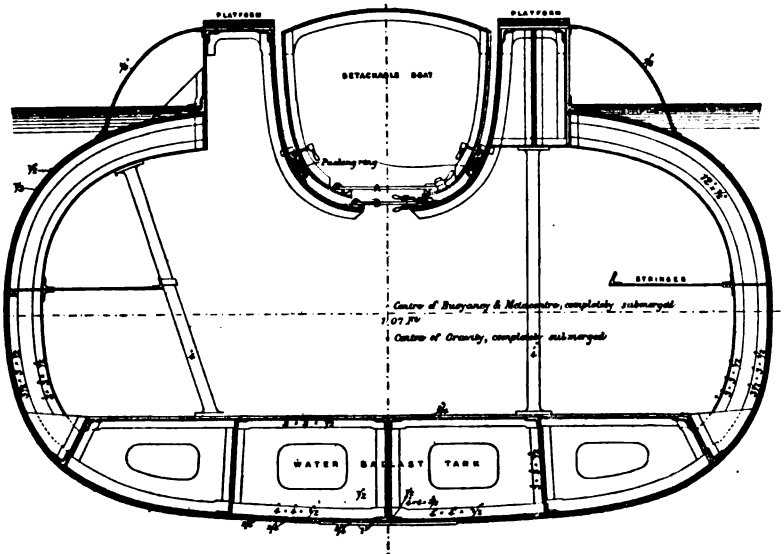

FIG. 7.—HOVGAARD'S DETACHABLE BOAT.

vessel itself; it rests on a saddle-shaped packing, against which it is tightly pressed down by means of a number of clips.

"Inside this packing is a circular door in the boat, and a corresponding and smaller one in the ship, arranged in such a way that it is possible to get up into the boat. This done, all the handles on the clips are turned. The water will probably now enter the space inside the packing, and if not, it may be made to do so through a small pipe leading from the outside to this space, and provided with a stopcock. The boat will now have a certain buoyancy, but will hang on by two main clips, placed one at each end of the detachable boat, and in mechanical connection with each other, so that they can only be let go both at the same time, thereby preventing jamming. When these clips are opened, the

should be fitted with one or more pairs of strong steel eye-bolts. In the plan of the Russian submarine, designed by Drzewiecki (Fig. 8), two eye-bolts A A can be seen, and by means of these the little vessels of this class could be lifted out of the water in a few minutes. On several occasions these eye-bolts proved the salvation of the two men forming the crew; for when, for some reason or other, the little vessel refused to rise (as happened more than once), a cable with clamp-hooks was attached, and the submarine hauled up to the surface.

Such a method as this would be impossible in larger vessels, even in the smaller Hollands. Nevertheless, if a series of such eye-bolts (say three pairs), were securely bolted to three steel containing-rings encircling the entire hull of the submarine, the raising of the

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vessel in the event of an accident would be very greatly simplified.

Perhaps, after expounding the above ideas, I shall be accused of forgetting the function of the submarine—that of a destroyer of battleships. I may be told that all the available weight must be applied to the augmentation of the means of offence, and that the safety of the crew must be always a subsidiary consideration. My firm opinion is, that it would be deplorable if the officers and men who so gallantly devote their lives to submarine navigation were not given the same chances of life, should a misadventure occur, as their fellows of the upper sea; and it is due to the nation that the future policy of our Admiralty in this respect be made public. On the surface, a large proportion of the total displacement is devoted to means of protection — armour belts, minute subdivision, protective decks, etc.—the object of these devices being more for protection against attacks by an enemy than against accidents. In the case of submarine vessels, their power of submergence is their best defence against the foe; and it is, therefore, to the minimising of fatal results, in the untoward event of an accident, that the efforts of constructors should be directed.

It will be a great step in the right direction when electric motors and their attendant troubles can be dispensed with altogether. Already the Italians have out-distanced us in this respect in their submersible, the *Glauco*, building at Venice from the designs of Engineer Cæsar Laurenti. This constructor employs a single oil motor for both submerged and surface work, while we stick stolidly to electric power and its tremendously weighty accumulators. A danger arises from the fumes these accumulators sometimes give off, in spite of all precautions. The entire crew of the *Narval* had to be conveyed home on one occasion, and two of them had perforce to be invalided out of the service. The *A1* submarine had a very bad time coming down to Portsmouth from the North, the batteries short-circuiting frequently and giving great trouble. It has even been stated, in reference to the recent accident, that the crew of the *A1* were suffocated by the first rush of sea-water mingling with the acid of the batteries and giving off fumes of chlorine-gas, which would, of course, soon prove fatal. Certainly, no intelligent person can believe what the jury were told—that the collision (which only slightly damaged the hull) suddenly deprived ten men of all power of motion, even that necessary to turn a handle.

Touching this question of death by shock, had the blow delivered by the *Berwick Castle* been of greater intensity, it is quite within reason to imagine that all the unfortunate occupants would have succumbed to the concussion; for, owing to the density of the ambient fluid, the entire force and subsequent vibration of the blow must of necessity be taken up by the submarine itself. In this particular a blow on a submerged body differs from a similar shock delivered on the surface, where the vibration, in which the real danger lies, radiates quickly through the thin medium of the air. It is owing to this peculiarity that the effectiveness of the torpedo is greatly due, for I need scarcely say that a charge of gun-cotton exploded against the hull of a ship in dry-dock would not be nearly so potent for damage as it would were the point of contact surrounded by a body of water.

An important step towards the insurance of safety for those whose duty takes them beneath the sea would be for those responsible to forbid manœuvring in narrow and much-frequented fair-ways. The jury at the recent inquiry recommended that "for the future, submarine manœuvres should not be carried out in the narrow fair-way"; but Captain Bacon pointed out that such a regulation would be impossible, and at the Coroner's suggestion the recommendation was, as many

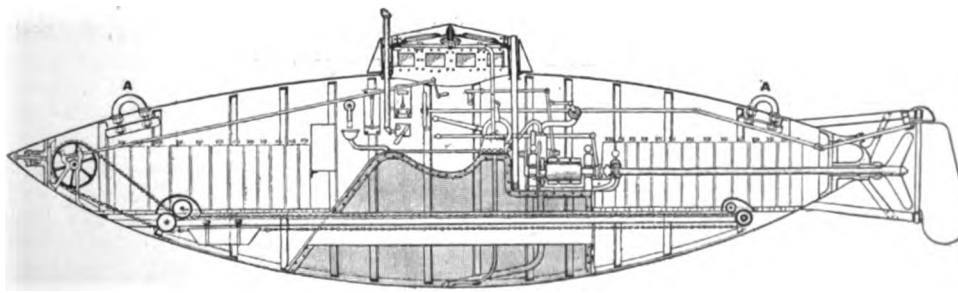

FIG. 8.—A RUSSIAN SUBMARINE, SHOWING EYE-BOLTS A A FOR LIFTING PURPOSES.

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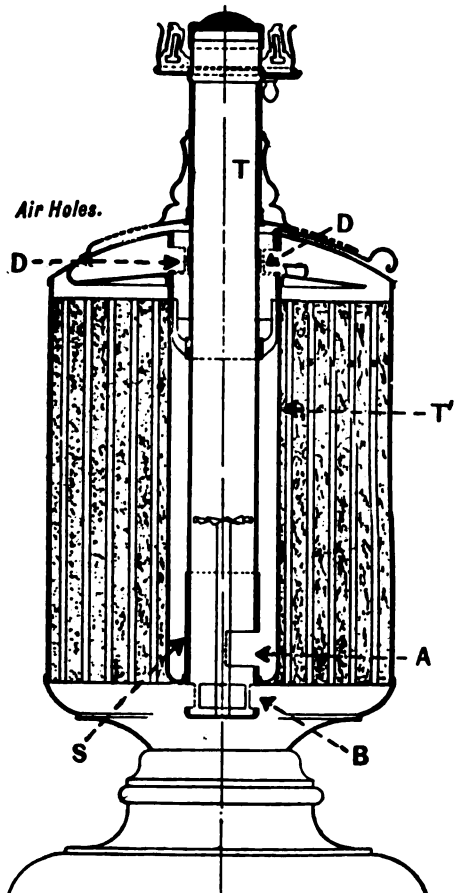
think very reprehensively, struck out. There are many places where manœuvres might be quietly conducted under war conditions. Certainly during war time it will be unusual if the mercantile traffic remained as constant and unwatched as during peace; and moreover, during war, captains of ships would keep a good look-out for such vessels as submarines, particularly in the neighbourhood of a naval base such as Portsmouth.

Time, no doubt, will rub many awkward corners off the present submarine boat; and we may feel assured that, if any improvements can be made in those under the White Ensign, the officers and men at present employed in these are the men to execute them.

THE PETROLITE LAMP.



THE Petrolite lamp is arranged in such a manner that air is continuously carburetted by passing over an absorbent non-combustible material charged with light hydro-carbon (petroleum) spirit. The burner tube T penetrates into the interior of the receptacle, its lower end fitting into a sleeve S. Air is admitted at the air-holes indicated in the diagram, and thence passes downward through the wide tubes T' and enters the burner-tube at the aperture A. Air also passes over the absorbent material charged with petroleum spirit by way of the aperture D, whence, charged with hydro-carbon vapour, it enters the burner-tube by way of the aperture B. At A and B apertures are made in the sleeve S and the burner-tube T; by rotating the burner-tube these apertures can be adjusted; arrangement is made that when the carburetted air apertures B are fully opened the air openings A are closed, and *vice versâ*. By this means the amount of carburetted air and pure air can be varied so as to give a non-luminous flame at the burner head; this flame is used to heat a mantle, as in the ordinary incandescent gas burner. There is no wick to this lamp and no free liquid; therefore if the lamp is accidentally upset or broken, an explosion cannot occur. The cost of light is less than a farthing per hour for fifty candle-power. The lamp is made by the firm of *Petrolite, Limited*, 66, Berners Street, London, W.

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THE FIBROUS CONSTITUENTS OF PAPER.

(Continued.)

By CLAYTON BEADLE.

Illustrated with Photo-micrographs by John Christie, F.R.M.S. Diagrams by the Author.

BEFORE proceeding further with our subject, we shall briefly review the work which has been done in the same direction by other observers. The only work of importance bearing on the qualities that we have recently discussed is that of Max Schubert. I prepared my manuscript for this series of articles before I became acquainted with Schubert's work, and I wish to express my indebtedness to my friend Mr. J. F. Briggs for having brought it to my notice.

Schubert made some experiments with the "shake" of the paper-making machine. He made "news" without shake and "news" with 170 and 225 shakes per minute, the amplitude of the shake being 8 mm. or $\frac{1}{3}$ inch in both cases. Making allowance for the difference in substance of the papers, and making other corrections for moisture, etc., etc., his results show that the average strength is increased by about 10 per cent. when working with 170 shakes per minute. Beyond 170 little or no improvement is noticed; it is therefore undesirable to increase the shake, as it causes more wear and tear on the machine wire without advantage to the sheet. These observations were made on a thin newspaper of from 53 to 55 grams per sq. meter. The mean elongation was increased by about 4 per cent. with 170 shakes per minute. Schubert's curves for thick writing paper (*i.e.*, 140 grms. per sq. m.) show that up to 159 shakes per minute there is little change in the direction of the fibres, and that a good influence on the "felting" is only got by the application of 240 to 250 shakes per minute. With thin "news" the least shaking immediately increases the mean breaking length. Up to 150 shakes per minute, the increase is considerable. Between 150 and 200 the changes are practically of no account, and a slight further improvement is only shown when 225 oscillations per minute are reached. The mean stretch is slightly influenced by the shaking, namely to the extent of 8 per cent. increase. With thick writing paper any shaking immediately increases the breaking length, but owing to the thickness of the web less than 150 oscillations are of little account. The improvement is greater between 150 and 200, and is most evident at the speed of 250. The mean elongation is favourably affected by the shake to the extent of 14 per cent. increase.

Schubert pursued an original method in investigating the "lie" of the fibres in the paper. He mounted specimens under the microscope and counted all the fibres on either side of 45° to the "machine" and "cross" directions. These he grouped either in the machine or cross direction, without taking into consideration the exact angle of the individual fibres. He made allowance for the length of the fibres; thus, the long ones counted as 3, the intermediate ones as 2, and the small ones as 1. My method made no difference between the length of the fibres, and I carefully observed the angle of each individual fibre, so as to get at the mean angle.

Schubert furthermore experimented by boiling 34 papers of different thicknesses with caustic soda, and noting the number of layers into which the paper separated after shaking, but without artificial assistance. Grease-proof parchment paper would not split, however thick it was; but other papers split if of greater substance than 45 grams per square meter. It is interesting to note that the average thickness of a separated layer is also 45 grams per square meter, which therefore appears to be the substance of the layers into which paper pulp naturally forms itself on the paper machine. Thin papers and those less than 45 grams per square meter do not tend to separate into layers, as they consist of one natural layer only. I have drawn attention to this property of "paper-lamination" in previous publications, and have endeavoured to explain how and why it is that paper naturally forms in laminæ on the machine, and what forces act upon it to bring about this result. Many papers do not separate into natural laminæ in the manner indicated by Schubert's results. Well-prepared hand-mades resist in a marked degree.

Schubert counted the fibres in the machine and cross directions in these separated layers, and his results are extremely interesting. They show that the fibres in contact with the

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machine wire have a much greater proportion pointing in the machine direction than those at the top surface of the paper. They show, furthermore, that as the shake is increased, so the fibres tend to set themselves in the cross direction. Schubert showed that a "substance" of 45 grams per square meter corresponds approximately to a thickness of 4 fibres. He constructed curves, showing certain relationships between the breaking lengths and stretches of different papers to the number of shakes per minute on the machine, from which some of the above-mentioned conclusions are drawn. Schubert's work deserves to rank as a classic.

Schubert's work affords proof that it is not correct to test a strip cut diagonally, with the idea of obtaining correct values for the mean breaking length and mean stretch. My work in this matter was conducted on lines quite different from that of Schubert, and without any knowledge whatever of his work; and it is interesting to note that, as far as our work overlaps, the two sets of researches led us by independent paths to similar conclusions.

Schubert proves that the ratio of breaking length in the "machine" direction to that of the breaking length in "cross" direction, when divided by the ratio of the fibres in the two directions, gives an average constant of 1·666; the same with the percentage elongations. These figures are averages of rather divergent components, and are of interest from a scientific standpoint only.

We have not yet drawn attention to the fact that the small laid lines in paper are very well brought out in Rostaing's Book-Plate 49. As this photo-micrograph shows fibres on the surface only, their direction cannot be made out, except in the raised portion between the lines, and as these are surface fibres only, no opinion can be formed of the direction of the fibres in the body of the paper.

As a high-class paper is only half made by the time it has passed over the drying cylinders, *i.e.*, at the stage of water-leaf, its physical qualities due to the various fibrous constituents are in a semi-latent state and only half-developed. It will therefore be necessary for us to consider carefully the next stage of treatment, *viz.*, the tub-sizing process, more particularly in the details which are likely to affect those physical qualities of the papers we have had under consideration. Ordinary water-leaf, providing that it contains no "rosin-size," is more or less of the nature of blotting-paper. If a drop of ink is allowed to fall on its surface it immediately soaks into the body of the paper and makes its appearance on the other side. If wetted by pressing against the tongue, it immediately shows the mark right through; where wetted it is rendered weak, so that the finger is easily poked through the wet mark. Such paper, for all ordinary purposes, requires to be sized, so that it will bear ink on its surface without allowing it to penetrate. Furthermore, water-leaf has a soft raggy "feel," and is too weak when the least bit damp. It requires for many purposes to be hard and rigid, and to have a "rattle," and to possess what is vulgarly known in the trade as "guts." These qualities are given to the paper either by rosin-sizing or by impregnation with gelatine. The manner and the extent to which the gelatine affects the paper is dependent on several factors which we shall now briefly enumerate.

In the crudest method of sizing hand-made paper, a bunch of dry water-leaf sheets are held, five to eight in number, between the finger and thumb by one corner, and dipped vertically into a gelatine solution (which should be kept constant in temperature) as in A., Fig. 1. The sheets, after reversing to allow the top corner to be immersed, are hung over lines in a loft to air-dry. This process of sizing is commonly known as tub-sizing, and the process of drying is commonly known as loft-drying. The same process can be performed in the web as in B, Fig. 1. The paper is passed in a continuous web over a roller into a solution of gelatine contained in a vat, which should be steam-jacketed to maintain a constant temperature. On emerg-

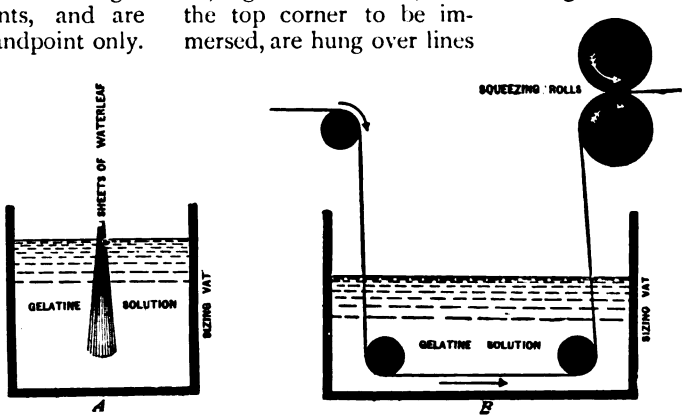

FIG. 1.—TO ILLUSTRATE METHOD OF "SURFACE SIZING."

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ing from the vat the treated paper is squeezed between brass squeezing rolls, to remove any excess, which falls back into the vat. We shall speak of this method as surface-sizing (Fig. 1, A and B), because by passing the web of paper vertically downwards and quickly through the solution, or by dipping hand sheets in a similar position, the air in the interstices of the paper has no chance to escape and so permit the gelatine to enter the pores. The paper is therefore coated only, instead of being permeated, the gelatine residing on the surface as in Fig. 2.

The reason that tub-sized paper frequently contains the greater portion of the size at, or near the surface only, is not necessarily due to the size not having penetrated in the first instance. It is not infrequently due to the fact that, in the course of drying the tub-sized sheet at too elevated a temperature, the gelatine rises through the body of the paper to the surface, and forms a film. During such drying the gelatine is abstracted from the body of the paper and comes to either surface.

In order to allow the gelatine to enter into the body of the paper, it is best to cause it to float on the surface for a short way before immersing it, until the top surface shows that the gelatine has permeated. This can be accomplished by hand, as in A, Fig. 3, and by machine in the continuous web, as in B. In the latter case a steam-jacketed vat is provided with sloping sides lined with copper or lead, to protect the sides from the corrosive action of the alum. The "water-leaf" meets the surface of the gelatine at an angle, and is made to travel in contact with the liquid without wetting the upper surface, and for such a distance as to enable the size to pass through the body of the paper to the upper surface. The paper is then made to dip under the gelatine solution, and then passed through the squeezing rolls. It might appear difficult to wet the under surface without allowing the liquid to flow over the top surface, but in practice this is not a difficult matter, as the under surface becomes wet, expands, and causes the edges of the paper to curl up, thus presenting a barrier to the flow of the solution over the top surface.

There are, however, important modifications of the above-mentioned methods. It is no longer the custom, in the best mills, to dip the sheets in bunches in the vat. The same process is imitated by clamping a large number of sheets together, and suspending them in clusters in a vat, which is filled with a hot solution of gelatine. The sheets are allowed to remain in the vats a sufficient length of time to allow the air to escape and the size to take its place in the pores of the paper. The sheets are then removed and

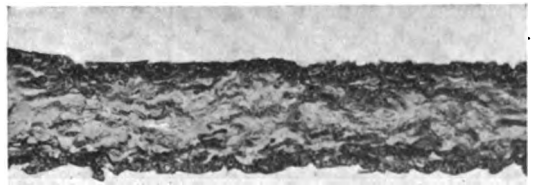

FIG. 2.—TRANSVERSE SECTION OF "SURFACE SIZED" PAPER, SHOWING GELATINE ON SURFACES.
(*Magnified 40 diameters.*)

passed through a pair of squeezing rolls, or stacked and pressed, then separated and hung up to loft-dry.

In another process the sheets are taken a few at a time, and passed through a solution of gelatine contained in a large shallow vat. The sheets are drawn along between an upper and a lower felt; the upper felt is perforated in order to allow the air to escape more readily. The machine is either actuated by a hand rack motion, by which the workman brings forward a batch at a time; or the felts are made to travel slowly and at a uniform speed through the solution. The vat must be long enough (say 30 or 40 feet) to admit of a fair output of sized sheets, and at the same time to allow the sheets to remain immersed in the size solution sufficiently long for a proper penetration. There should be no air bubbles rising through the liquid close to where the sized sheets emerge and are discharged. The bunches of sheets are fed on to the felts, say eight in each batch, and from one to three abreast, according to the size of the sheets.

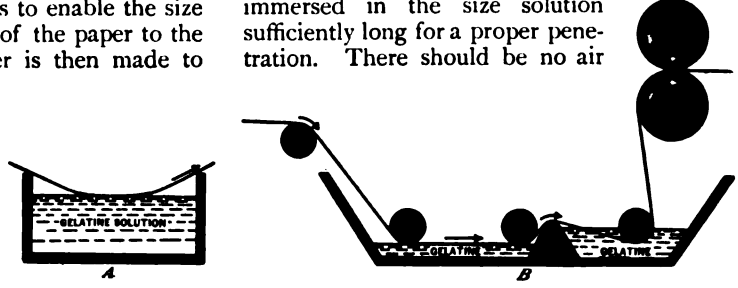

FIG. 3.—METHODS OF SIZING PAPER SO AS TO ENSURE THAT THE SIZE PENETRATES INTO THE INTERIOR OF THE SHEET.

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The felt carrying the water-leaf travels at a very slight incline, so as to allow the air to escape more easily. The solution is only just deep enough to ensure proper immersion as the sheets travel horizontally the whole length of the vat. The temperature of the solution is maintained either by steam-jacketing the bottom, or fitting it with a steam coil. The latter, although perhaps cheaper, is much more difficult to cleanse. Various modifications of this plant are in use.

Beyond the mode of treating the size, there are other and no less important factors which influence the quantity of size absorbed by the water-leaf. The rate at which the web of paper passes through the vat is, of course, a determining factor. If a high speed is required, a longer vat must be used to give sufficient time for the immersion. As the rate of impregnation is dependent upon the viscosity of the solution, and this is again dependent upon the temperature, this last must be carefully controlled. The higher the temperature the lower the viscosity, and as a consequence the more rapid the rate of penetration. Then again, the percentage strength of the gelatine solution affects the viscosity; the greater the percentage strength the greater the viscosity. A size of high strength, therefore, permeates more slowly than one of low strength. The amount of moisture contained in the water-leaf before it passes into the size solution will affect the rate of impregnation; within limits, the moister the water-leaf the quicker the impregnation: thus a bone-dry water-leaf takes up the size solution less rapidly than one containing an appreciable amount of water. In order to ensure regularity in drying the water-leaf, it is generally advisable to bone-dry it, *i.e.*, to deprive it even of its natural moisture. If the water-leaf were brought down to, say, 7 per cent. of moisture, there is a danger of the paper being moist in patches. The result of this would be to cause irregular soaking up of the gelatine, so that the paper would vary locally in the amount of gelatine it contained. This is liable to cause a blotchy appearance in the paper, both when looked *at* and when looked *through*. Moreover, when the water-leaf is damp, the web, which is extremely tender as it passes through the sizing trough, is liable to break and cause a lot of trouble, expense, and inconvenience. I have known the web broken in the trough by a rat plunging into the hot size and swimming from one side of the vat to the other. The least touch will cause a break.

In spite of the comparative slowness of absorption of the bone-dry water-leaf, it is considered advisable to bone-dry it before allowing it to pass through the sizing trough, for the reasons above mentioned. The presence or absence of soap, and the proportion of soap used, are determining factors. Soap is dissolved to a clear solution in hot water, and added to the hot size solution, before or after the alum. The soap must be of such a nature that when mixed with the gelatine, and subsequently with alum, no curdling or separation of the fat acids, or compounds of the fat acids and alumina, occurs. This can only be ensured by using soap of a particular character which forms a fine emulsion evenly distributed throughout the mass. Soap tends to give a certain amount of opacity to the paper, but the extent of its effect in this direction is doubtful. It however gives desirable qualities to the finished paper; among them may be mentioned the lubrication of the fibres. Some papers have a disposition, when cut with the guillotine, to cause the knife to go through with a bang. Papers containing soap, preferably added in the chest, permit the knife to glide evenly through the stack of paper. It is also possible that a lower grade of gelatine can be used without prejudice to the colour of the paper: the soap being held in fine white emulsion, disguises the colour of the gelatine.

We have so far considered only water-leaf which has not previously been sized with rosin. In consequence of the great expense of tub-sizing with gelatine, paper-makers use, as far as possible, the cheap forms of gelatine. This is very doubtful economy. I am strongly of opinion that a deal more good might be done by the use of a high-class gelatine in small percentages, but imparted to the paper and dried in such a way as to produce its maximum effect. So far this subject has received little attention at the hands of paper-makers, who prefer to reduce their cost of production by using a low-grade gelatine or glue, or by the addition of rosin size in the chest, which renders the paper more or less ink-proof, and prevents it taking up so much gelatine solution when passing through the vat. Twenty years ago tub-sized papers contained no rosin size; now, so far as my knowledge goes, the greater bulk of them do, although the best of them still do not.

A web of paper sized as Fig. 1 would take up perhaps 30 per cent. less weight of solution than if sized by the method shown in Fig. 3. The percentage of size taken up by the paper is also controlled by varying the percentage strength of the size solution—the most ob-

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vious way of controlling it — but as the amount of moisture taken up by the paper has to be dried out of it again, and as the cost of this is considerable, in consequence of the drying being effected at a low temperature to preserve the sizing qualities of the gelatine, manufacturers generally prefer to control the percentage by varying the impregnation of the paper; and this is frequently done by adopting one or other of the methods illustrated in Figs. 1 and 3, according to requirements, and varying the strength of the gelatine solution between 4 per cent. and 7 per cent.

The amount of solution retained by the treated paper is dependent, of course, upon the amount of pressure on the squeezing rolls. To allow of the paper being properly handled afterwards, the pressure on the rolls must be sufficient to prevent the surface of the moistened paper being sticky, otherwise there is likely to be trouble in the subsequent drying operations. On the other hand, if too great a pressure is applied, especially with papers of a spongy nature, there is a liability of breaking up the microscopic films of gelatine, which fill the interstices between the fibres. When these disappear the paper is no longer ink-proof. The pressure on the rolls can therefore only be varied within certain limits. The temperature must not be raised to a point likely to injure the gelatine solution, but it may with safety be varied between 85° and 130° Fahr.

One of the most important means of control is by the addition of alum. Alum affects the viscosity of gelatine solutions in a very curious manner. If a hand-bowl containing a good-class gelatine solution, say five per cent., at a temperature of 95° Fahr., is stirred by the hand whilst a few drops of alum solution are added, a thickening effect will be noticed; on further addition of alum this will reach a maximum: the solution may become almost a jelly. On further addition of alum it becomes liquid again, until it becomes even less viscous than the original solution containing no alum. The size man controls the penetration of the size by the addition of alum. If he finds that he has overshot the mark with alum, he adds more size containing no alum, and thoroughly mixes the ingredients. If he wishes to increase the viscosity or "thickness" of the size in the trough, he adds more alum and thoroughly mixes, but he should never use so much alum as to anywhere nearly reach the maximum viscosity as indicated in Fig. 4. If he has overshot the maximum and got a thin size by the addition of too much alum, the size is said to be "killed," as it is nothing like so effective as a size of the same strength with the proper amount of alum added to it; besides which, the addition of too much alum is extremely wasteful, and the excess of alum gives to the paper an acid reaction which is considered undesirable for many purposes. As the rate of penetration of size into paper is *ceteris paribus* inversely proportional to the thickness (*i.e.* viscosity) of the size solution, the dotted curve, Fig. 4, which is merely an inversion of the plain line curve, is made to represent the change of power in permeating water-leaf on addition of alum.

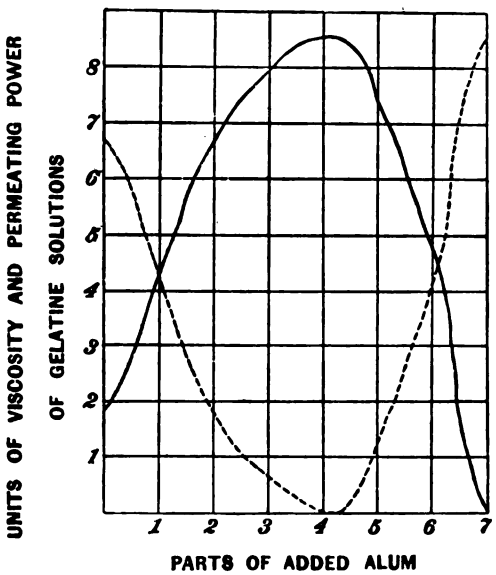

FIG. 4.—CURVES SHOWING THE VISCOSITY OF GELATINE SOLUTIONS, FOR VARIOUS PERCENTAGES OF ALUM ADDED.

The curve drawn thus——— gives the viscosity, and that drawn thus– – – the permeating capacity of the solution.

The somewhat strange behaviour of size when mixed with alum, as exemplified by the above diagram, is capable of scientific explanation. Size and glue consist of two distinct yet similar compounds, known respectively as gelatine and chondrin. Chondrin is thrown out of solution by alum and several other compounds which do not precipitate gelatine. Size, glue, and commercial gelatine consist of mixtures of gelatine, chondrin, and the non-gelatinising substances produced by the long boiling and oftentimes over-heating of their solutions.

If it is considered desirable to prevent the paper becoming body-sized, we have yet another means of doing so, and that is by

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adding alum to the chest in sufficient quantity to give excess of alum to the dry waterleaf. This, when it comes in contact with the size solution, coagulates the gelatine in the surface, and the coagulated gelatine has no power of penetration. This can be controlled, of course, by the amount of alum added to the chest. This result can hardly be achieved without wasting a considerable amount of alum, unless the "backwater" of the machine is saved and used over again to the best advantage.

Some of the best mills in this country have for fifty or sixty years, or perhaps from the advent of the Fourdrinier machine up to a few years ago, combined the manufacture of paper with tub-sizing and drying the same as a continuous process. There are obvious disadvantages in this. The rate of travel through the sizing trough has to be the same as that of the "wet-end" of the paper machine. This may or may not suit the sizing. The paper comes away from the drying cylinders bone-dry and hot, and plunges at once into the size solution. Some advantage might be gained by reeling the paper after it is dry and allowing it to settle itself down and cool in the waterleaf, so as to allow it to get to its normal condition before the tub-sizing process; but perhaps the greater disadvantage is found in the drying. The wet-sized paper contains about 50 per cent. of gelatine solution and 50 per cent. of air-dry paper if body-sized; if surface-sized, from 30 to 40 per cent. of gelatine solution and 60 to 70 per cent. of air-dry paper. As the gelatine solution contains about 5 per cent. of air-dry gelatine, 95 per cent. of the solution is water which has to be removed by the drying process. Roughly speaking, as a maximum with body-sizing, for every ton of paper produced at the cutter one ton of moisture has to be evaporated. As this evaporation has to be conducted at a low temperature by means of dry air, the process is of necessity a slow one; and where revolving skeleton drums are used, in order to keep pace with the output of the paper machine, provision has to be made to dry a length of from $\frac{1}{2}$ to $\frac{3}{4}$ of a mile in continuous web. If the paper is reeled, either before or after sizing, or both, the speed of sizing is independent of that of the paper machine; and if the machine is at times only producing soft size papers, *i.e.*, papers sized only with rosin, the sizing plant can work off any accumulated stock of unsized water-leaf. It is generally admitted that reeling, after sizing and before drying (*i.e.*, immediately after passing the squeezing rolls), and allowing to remain in a damp condition, so as to permit the size solution to more thoroughly permeate the paper, gives a better result than if the sized paper is immediately dried after immersion. The best plan therefore is to reel the water-leaf, and to allow the reels to stand some hours or days; then to unreel and pass through the sizing vat and to re-reel; and when the reels of damp sized paper have been standing a sufficient time, to unreel and pass over the drying plant.

The skeleton drums previously referred to are provided, in their interior, with rapid rotating fans, which are speeded up in sections. These fans drive the air against the surface of the paper and so increase the rate of drying. The impinging of air on the surface of the paper would tend to keep the temperature of the paper below that of the surrounding air by reason of the rapid evaporation. This is a most desirable thing, as will be hereafter explained. But the paper is kept under a certain amount of tension by this treatment, and in a state of quiver by the rapidly rotating fans. This, I am disposed to think, is undesirable, and likely to break up the microscopic films of gelatine in the interstices of the paper. It is possible to produce a hard-sized paper with a small percentage of gelatine by dipping the water-leaf (as in Fig. 11) and slow drying in loft, when the same amount of gelatine produces a poor result if the paper is dried over skeleton drums. This fact would lead us to suspect that the fans have a bad influence. It is most desirable that the drying should be done naturally and slowly, without agitation, and above all things, at a low temperature. This is now, in a large measure, accomplished by a machine which takes the wet paper along in festoons by a slow gliding motion through a drying chamber, at such a speed that when it emerges at the other end it is air-dry. This process admits of a natural shrinkage during the drying, and the paper remains quiescent, but it is far short of perfection.

The drying of tub-sized papers is perhaps one of the most difficult problems presented to the paper-maker. Gelatine has no sizing effect if dried over a steam cylinder. The heat liquefies the gelatine, and it dries merely as a coating to the fibres, the spaces between them being left vacant. The gelatine is not destroyed, but is without any effect; it merely coats the individual fibres and is quite discontinuous. Although this is a well-known fact to all paper-makers, many of them think there is no harm in using a certain amount of artificial heat in the air used for drying. If we lived in a very dry climate, the air would

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have enough drying power at about 50° F. to dry the moisture out of the sized paper; but unfortunately, if one takes the records of the Meteorological Office, the average percentage saturation, in many of our manufacturing districts, is found to reach 80 per cent., and frequently borders on 100 per cent. It is impossible, therefore, to obtain drying power out of the air at ordinary temperatures, unless we give to it a certain amount of artificial heat, and this is generally what is done. The golden rule should be :—Dry the sized web at a temperature below the setting point of the jelly. The wet size in the paper should get to a jelly before the drying operation, so that instead of drying water out of a gelatine solution, we are really drying water out of a solidified jelly contained in the interstices of the paper. So long as the temperature of the air is above that of freezing point, and there is sufficient drying power in the air, drying can be conducted properly; but when once the warmth of the air liquefies the jelly the sizing becomes defective.

If a good class of gelatine is used, a smaller percentage of it remains as a jelly at any given temperature up to 60° F. than with a low-class gelatine, and the sizing effect with the more expensive gelatine far outweighs the additional cost. In other words, we can obtain a firm jelly at a cheaper rate by the use of a more expensive gelatine. It follows, therefore, that at the temperature at which tub-sized papers are now dried, a greater amount of gelatine is used than would be necessary if a lower temperature were maintained. When some cheap process is forthcoming for the drying of air at a low temperature, it will greatly aid the manufacturers of tub-sized papers.

Tub-sized paper is often improved by sprinkling it with water after drying, stacking it, and again drying it; but care must be taken to prevent the development of liquefying bacteria and moulds, which destroy the sizing quatities of the gelatine. Such a process can only be of advantage where the drying has been badly done in the first instance.

Cotton, linen, hemp, jute, wood, all behave differently with size solutions, and require different quantities of gelatine. The manner in which these fibres are beaten and felted together also has a material effect upon the sizing qualities. This is a subject outside the question which we are now discussing, and one on which much has been written.

Finally, calendering, plate-glazing, rolling, etc., affect the sizing qualities. A paper which has been highly glazed under pressure between copper or zinc plates is often reduced in its ink-bearing qualities. It is easier, therefore, to produce a hard-sized paper with a rough surface than one which has been highly glazed. We have previously mentioned that tension on the finished paper destroys the ink-bearing qualities by breaking up the films of gelatine; pressure has the same effect. When single sheets are loft dried they are more or less rough, and show a mark which is removed by subsequent pressing; but the system of drying over skeleton drums, whatever else its effect may be, produces a paper perfectly smooth and free from cockles, without any pressing or glazing.

(To be continued.)

HOW TO COLLECT SPILLED MERCURY.

MERCURY spilled on a table or floor is somewhat hard to collect, unless special precautions are taken, owing to its tendency to divide into small globules which roll away at the slightest touch. If a wet ring is made round the spilled mercury, by the aid of a wash bottle or other similar means, it will be found that the globules of mercury cannot readily cross this ring; the mercury can then be readily collected in a small shovel made from a piece of thin card, or even in an ordinary envelope.

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THE METALLOGRAPHY OF STEEL.

By PERCY LONGMUIR, of the National Physical Laboratory.

II.

TWO further illustrations of the structures of hardened steel are given in Figs. 13 and 14, the former representing a table knife blade and the latter a razor. A table-knife, although essentially a hardened steel, has to some extent had its hardness modified by the process of tempering, as illustrated in the springing properties of the blade. Razors, on the other hand, are extremely hard, possessing no ductility, but carrying a very keen cutting edge. These two articles represent the extremes found in cutting tools of this description; razors and kindred surgical instruments, whilst brittle, possess a keen cutting edge, and the keenness diminishes as the ductility increases, until the lessened cutting power of the table-knife is reached. As compared with Figs. 11 and 12 of the preceding article, the structures shown in Figs. 13 and 14 present no noteworthy differences. Both apparently contain two constituents; the distribution of the white constituent in Fig. 14 is, however, slightly different from that of Fig. 13.

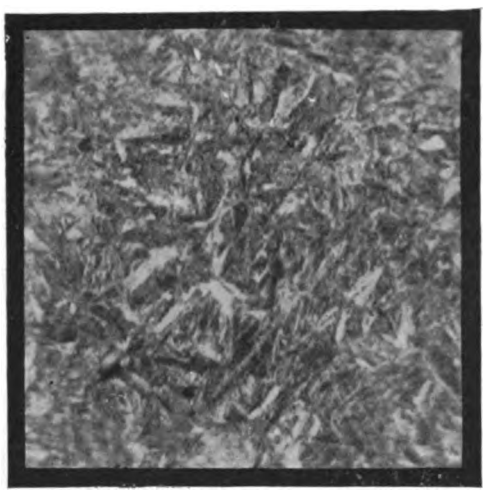

FIG. 13.
PHOTO-MICROGRAPH OF TABLE-KNIFE BLADE.
Magnified 1,000 diameters.

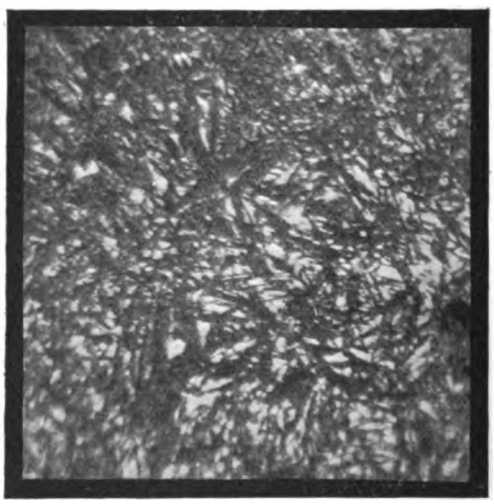

FIG. 14.
PHOTO-MICROGRAPH OF RAZOR BLADE.
Magnified 1,000 diameters.

All users of hardened tools* know how readily they "let down" or lose their cutting edge if heated; thus, in practice, if a tool is likely to heat, precautions are taken to cool the "nose" or cutting surface. If moderate heat generated by friction results in a loss of cutting capacity, this loss should mark the beginning of a structural change from the hard to the soft condition.

This decomposition marks the tempering process, and in arresting it at the desired point lies the success of the operation. In considering the influence of moderate heat on the foregoing structures it must be remembered that two of them, the saw blade and table-knife, represent tempered steels, the former, however, having received only a moderate amount of tempering. The saw blade, after heating to a dark blue heat, presents the structure shown in Fig. 15, which on comparison with Fig. 12 will show that the heating has permitted some internal change, for the white areas are now more pronounced and show a tendency to gather together. The file (Fig. 11), similarly treated presents a structural rearrangement, as shown in Fig. 16, where the collection of white areas will be chiefly noted. The hard razor (Fig. 14), after heating to a blue heat, presents a structure as depicted in Fig. 17. The term "blue heat" in these experiments represents the colour observed on the polished

* Applicable to ordinary carbon steels, not special alloys of the "high-speed" type.

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surface; immediately on reaching it the samples were withdrawn from the source of heat and cooled in air, the cooling therefore occurring with fair rapidity.

A hardened steel, if heated to a full red heat and slowly cooled, regains its original softness. Thus Fig. 18 represents Fig. 14 after such treatment. It will be noted that the structural change commencing at a low temperature is entirely completed at a higher one, the structure now consisting of the familiar pearlite and cementite. Comment on these hardened and tempered structures is for the moment reserved. For the present, however, the two following facts may be noted:—

1. Four entirely different hardened steels all present at high magnifications indefinite structures consisting of black and white constituents differing only slightly from each other.

2. That hardened steels are extremely sensitive to heat, a comparatively low temperature marking the beginning of a structural change which is completed at a higher one, when the steel returns to its normal soft condition.

III.

The Literature of Hardened Steel.—The *raison d'être* of the hardening of steel by quenching is a matter of controversy, a fact readily appreciated when the comparative youth of metallography is considered. Controversy may serve a useful purpose by clearing the ground of much lumber, but

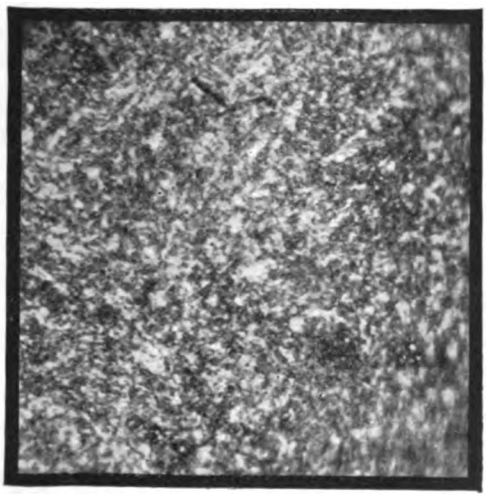

FIG. 15.
PHOTO-MICROGRAPH OF TEMPERED SAW BLADE.
Magnified 1,000 *diameters.*

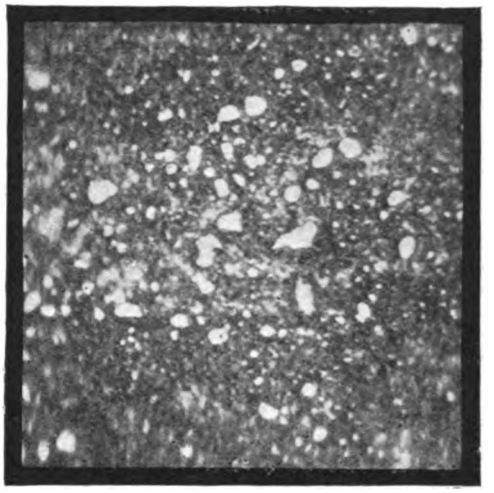

FIG. 16.
PHOTO-MICROGRAPH OF TEMPERED FILE.
Magnified 1,000 *diameters.*

unfortunately during the heat of battle the student suffers. Not only so, but the progress of the science is retarded, and its practical application delayed. For instance, the practical steel hardener of to-day, with his traditional empiricism, is actually in advance of the scientist. Constant experience in hardening and tempering develops in the individual a skill which enables him to turn with facility from one steel to another, and to produce regularly successful results. Any examination of hardening and tempering conditions usual in practice shows that the essential features for the production of a certain degree of hardness or "temper" are realised. The underlying reasons may not be known, but the methods followed, although empirical, achieve the desired end.

A careful study of much of the literature on the hardening of steel reveals, not the extent, but rather the lamentable lack of knowledge. A vast amount of research has been devoted to the subject, and a certain amount of information gained. This gain emphasises the urgent need for further and wider work, conducted under better experimental conditions than have prevailed in much of the past research.

In discussing the salient features of this literature, some digression is necessary. If steel be regarded as an alloy of iron and carbon, the carbon being in combination with some of the iron, then the alloy will structurally consist of two primary constituents, *viz.*, ferrite and cementite, and a mixture of these two will give a secondary product—pearlite.

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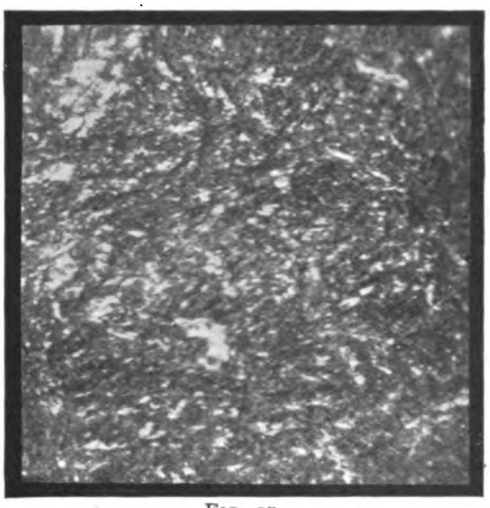

FIG. 17.
PHOTO-MICROGRAPH OF TEMPERED RAZOR BLADE.
Magnified 1,000 diameters.

Now M. Osmond recognises the following as primary constituents :— ferrite, cementite, pearlite, sorbite, martensite, troostite and austenite. Of these the first three are familiar, whilst the fourth—sorbite—has, to some extent, been noted, and its near approach to pearlite indicated. The last three are peculiar to hardened steels. Martensite gives the appearance of a system of interlacing fibres, frequently arranged so as to form triangles. It may be produced by quenching steels of varying carbon content (0·3 to 1·3 per cent.) from temperatures exceeding the recalescence point or above 780°C. Troostite is obtained by quenching steels in the middle of their transformation, or at a temperature in the vicinity of 700°C. A less energetic quenching than is required in the case of martensite results in troostite ; or, if the former be tempered, the latter is obtained. Troostite occurs as a dark border surrounding martensite. Austenite represents a constituent softer and less magnetic than martensite, with which it is often associated. The necessary conditions for its production are a carbon content in the steel of 1·5 per cent., a quenching temperature of 1100°C., and a quenching bath at 0°C. An etching medium of 10 per cent. hydrochloric acid colours martensite, but not austenite, the latter remaining white. The following quotation is germane to this present survey.

* "To obtain austenite, the temperature of the steel must be above 1000°C., and the temperature of the quenching bath a little below or just at 0°C., and the proportion of carbon must exceed 1·1 per cent. With carbon steels I have never obtained pure austenite, but mixtures with martensite or hardenite. The amount of austenite increases with the amount of carbon from 1·1 per cent. where there is none, to about 1·6 or 1·8 per cent. where there may be 70 per cent. Beyond that, no matter what is done, it produces a separation of cementite, so that the proportion of dissolved carbon is diminished, and consequently the proportion of austenite no longer increases."

By way of comparison, the following quotations are given from Professor Howe's work, "Iron, Steel and Other Alloys"* :—

"Austenite, the characteristic and chief constituent of suddenly cooled (*i.e.*, hardened) steel, is a hard brittle mass with a needle-like structure, and is a solid solution of carbon in iron, the proportion of carbon varying from nothing up to about 2 per cent."†

"Martensite, troostite, and sorbite are transition forms between austenite on the one hand, and ferrite and cementite on the other, probably containing all three of these substances, but in varying proportion."

The two quotations relating to austenite indicate to some extent the confused condition of metallography. If, however, an attempt is made to classify the subject, something like the following will be obtained.

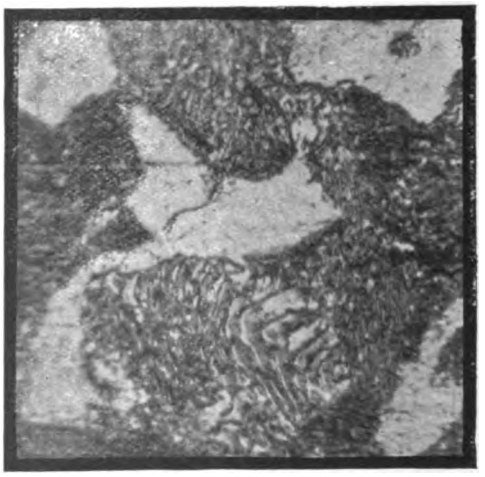

FIG. 18.
PHOTO-MICROGRAPH OF ANNEALED RAZOR BLADE.
Magnified 1,000 diameters.

* "Microscopic Analysis of Metals" (Osmond and Stead), pages 98, 99.

* Page 179.

† Professor Howe recognises the species austenite—variety martensite.

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Martensite consists of a solid solution of carbon in iron, its hardness increasing with the content of carbon; in other words, from the hardness of soft iron to that of the hardest steel. Martensite is a constituent of hardened steels, and pearlite of annealed steels, and between these two limits there are intermediary ones, amongst which may be noted sorbite and troostite. If the quenching has not been quickly effected, part of the martensite is transformed into troostite, whilst a slower but still fairly rapid cooling gives sorbite. That is to say, troostite marks the beginning, sorbite a further stage, and pearlite the last one in the decomposition of martensite. It is admitted by all metallographists that the distinguishing traits between pearlite and sorbite are less clear than those between troostite and martensite; yet even troostite possesses a somewhat indefinite character. Austenite is only met with in steels of high carbon content when quenched in ice-cold water, and is always necessarily associated with martensite.

In concluding this section, there remain yet to be noticed the views advanced by the Carbonists. In 1895, Professor Arnold published his discovery of the "saturation point," and showed that an annealed steel containing 0·89 per cent. carbon structurally consisted of pearlite. He also showed that a saturated steel, on hardening structurally, consisted of one constituent formed by the union of the ferrite and cementite of the pearlite, and corresponding to the formula $Fe_{24}C$. A steel containing 0·38 per cent. carbon, after hardening presented a structure containing two constituents, ferrite and hardenite, or $Fe_{24}C$. A hardened high carbon steel (1·47 per cent.) showed a structure the matrix of which corresponded to the structure of the saturated (·89 per cent. C.) steel, but was interspersed with fine meshes and striæ of cementite. In 1902, Messrs. Arnold and McWilliam published an examination of the microstructure of hardened steel,* from which the following summary is extracted:—

"The clear and definite constituents of hardened steel consist of (*a*) hardenite, $Fe_{24}C$, of which the whole consists only in the case of 0·89 per cent. carbon steel; (*b*) ferrite, which segregates more or less in unsaturated carbon steels, in spite of the rapid action of quenching; (*c*) cementite, which segregates more or less in supersaturated steels, in spite of the rapid action of quenching. The indefinite portions of hardened steels consist in unsaturated carbon steels of hardenite containing more or less unsegregated ferrite, or in supersaturated steels of hardenite containing more or less unsegregated cementite.

"Martensite is not a constituent, but a crystalline structure developed at high temperatures. It is marked in saturated carbon steels by preferential etching lines, in unsaturated carbon steels by striæ of ferrite, and in supersaturated carbon steels by striæ of cementite."

FIG. 19.
"WATER CRACK," OBTAINED BY QUENCHING FROM TOO HIGH A TEMPERATURE.
Magnified 1,000 diameters.

IV.

Practical Considerations.—A consideration of Section III. must necessarily be accompanied by an examination of at any rate two practical features which are found respectively in the content of carbon and the quenching temperatures. Taking the carbon content first, in practice an infinity of hardened tools are made, and to secure the necessary variations of hardness the carbons of the steels are varied from about 0·5 to 1·5 per cent. It must be remembered that carbon is varied in addition to the subsequent tempering given to modify the hardness induced by quenching.

* Journal of the Iron and Steel Institute. No. 1, 1902.

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The following table shows how the carbons are varied to suit special requirements.

Content of Carbon in Steel.	Purpose for which the Steel in the form of a Hardened or Tempered Tool is Suitable.
0·50	Springs.
0·60	Stamping dies.
0·65	Clock springs.
0·75	Hammers, shear blades, axes for wood, mint dies.
0·80	Boiler punches, screwing dies, cold setts.
0·90	Edge tools, slate saws.
0·95	Circular saws, pens.
1·00	Cold chisels, cross-cut saws.
1·10	Drills, large files, hand saws.
1·20	Granite and marble saws, mill chisels.
1·30	Harder drills, cutters, spindles, turning tools, and medium files.
1·40	Saw files.
1·50	Turning tools for chilled cast-iron razors and surgical instruments.

From this table it will be noted that the highest content of carbon is found at 1·5 per cent., and in practice this content is seldom exceeded. It will further be noted that between 1·2 and 1·5 per cent. carbon, only the hardest of tools are found, whilst the comparatively large class designated as "edge tools" contain 0·9 per cent. carbon.

Turning to the second feature, it is found in practice that, for very good reasons, quenching temperatures do not exceed 1000°C. Ordinary carbon steels, if quenched in cold water, from this excessive temperature develop cracks, technically termed "water-cracks." Such a crack is shown in Fig. 19, and was obtained by quenching a piece of 1·2 per cent. carbon steel from a temperature of 1000°C. in water at 13°C.

Naturally, hardening temperatures vary somewhat with the carbon content of the steel and particular conditions, but as a general average a temperature of 850° may be given. The liquids employed for quenching vary; as a general rule, however, their temperatures do not fall so low as 0°C.

A comparison of these features with some of the statements outlined in Section III. is not without interest. At present this comparison is restricted to the following notes. Professor Howe described austenite as "the characteristic and chief constituent of hardened steel"; but the preceding quotation from M. Osmond shows that the essential conditions for producing this constituent are high carbon in the steel, a quenching temperature of at least 1000°C., and an ice-cold quenching bath. It has already been shown that:—(1) only in the hardest steels does the content of carbon exceed 1·2 per cent.; (2) in no case does the quenching temperature exceed or approach 1000°C.; (3) the temperature of the quenching baths is above 0°C. Evidently then the requisite conditions for the production of austenite do not prevail in practice, for even in the comparatively few cases where the carbon is sufficiently high, the quenching temperature is always too low. Sorbite, as already shown, represents pearlite in a fine state of division; there yet remain martensite, troostite, and hardenite for consideration. Reference to the structures of hardened steels already figured will show that, generally speaking, they consist of a dark matrix interspersed by more or less irregularly-shaped white areas and patches. Under certain conditions the structure shown in Fig. 14 could be described as martensite (dark) and austenite (white), but—and herein lies an important point—the conditions under which the structure was produced preclude the formation of austenite if that of martensite be accepted. The nearest approach to martensite is shown in Fig. 13, but the black lines are not sufficiently needlelike or rectilineal to coincide exactly, a remark also applicable to Fig. 11, whilst Fig. 12 is decidedly not martensitic. Troostite, it will be remembered, is a product developed by comparatively low quenching temperatures, or resulting from the decomposition of martensite by tempering. The tempered structures already given have shown that moderate heat marks the beginning of the segregation of a white constituent, as illustrated in comparisons of Figs. 15 and 13, and Figs. 16 and 11. The tempered razor certainly shows large quantities of a black substance which, however, does not appear to be troostite.

The white constituent of Fig. 14 is relatively harder than the black one—further proof that it does not correspond to austenite, for austenite is softer than martensite.* It does, however, correspond to cementite, both by hardness tests and etching characteristics. As this structure has been produced by quenching at a temperature below 1000°C., it should, according to the views enunciated on martensite, consist entirely of this constituent. The photograph given is perfectly typical of the whole structure, and it consists of two entirely distinct constituents, one of them cementite. Similarly, all the hardened structures given show two constituents. Taking as a further example Fig. 13, the white areas

* "Microscopic Analysis of Metals" (Osmond and Stead), page 170.

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of this structure are distinctly softer than the dark ones, and they correspond in all respects to ferrite, two features which recall the quotations given from Messrs. Arnold and MacWilliam's research.

The writer has examined many different samples of commercial hardened steels in order to check the accuracy or otherwise of this statement: an examination which has shown that hardened steels contain two constituents, one of them decreasing with a progressive increase of carbon until "edge-tool temper" is reached, a point marking an almost homogeneous structure. In other words, as in annealed steels so in hardened ones, free ferrite decreases with an ascending carbon, with this exception—that the pearlite of the annealed steels is replaced by the dark structureless constituent in the hardened steels. This dark constituent assumes a form characteristic of the rapidity of quenching, and, in certain cases, as in slow quenching or subsequent tempering, may contain minute particles of free ferrite. On the other hand, drills, large files, and similar tools which correspond to Arnold's supersaturated steels, all contain cementite. Speaking entirely from the point of view of commercial hardened steels, there is every reason to suppose that the white constituent of an unsaturated carbon steel is ferrite, that of a supersaturated, one cementite.

Is the black constituent martensite or hardenite? Practically, a mere term is immaterial, and the user of a drill, knife, or razor cares not a whit what particular "ite" the properties of his implement are due to: his natural demand is found in the existence of the properties. But when considered in its true sense, that of exactness, terminology then assumes some importance, and naturally we expect an exact term to denote exact properties. Now martensite, as a constituent, is described as of varying hardness, according to its content of carbon, a variation which evidently precludes the possession of exact properties.

Further, martensite contains from nothing up to 2 per cent. carbon, and is produced by quenching from a full red heat; therefore, a piece of iron containing 0·08 per cent. carbon so quenched ought to consist of dilute martensite. Reference to Fig. 8 of the first article shows the structure of quenched Swedish iron, and it will be noted that no approach to martensite is shown.

On the other hand, hardenite indicating a compound $F_{24}C$ represents an exact substance and, viewed in this light, the increase in hardness of quenched steels, always observed with an increase of carbon, is naturally due to the formation of larger quantities of the compound, and consequently diminishing amount of the ductile ferrite. Further increase in hardness with similar increase of carbon is evidenced in the distribution through the hardenite of the hard and brittle cementite.

A NEW PROPERTY OF THE MERCURY VAPOUR LAMP.

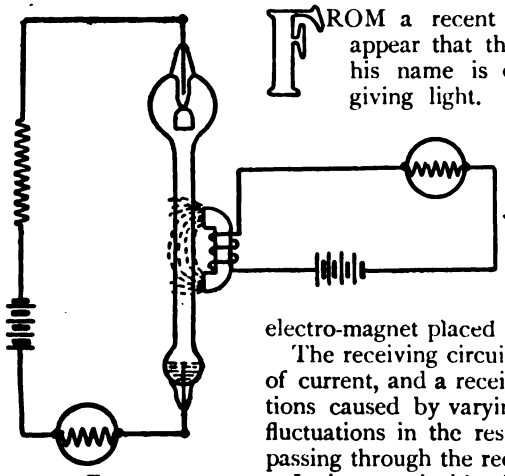

FIG. 1.

FROM a recent patent specification of Mr. Hewitt, it would appear that the mercury vapour lamp or tube associated with his name is capable of yet another function than that of giving light. The inventor has discovered that the resistance of his lamp is appreciably affected by the presence of a magnet, so placed that its flux passes through the tube and the vapour it contains. He arranges the apparatus in the manner indicated in Fig. 1. On the right-hand side is the transmitting circuit, consisting of a battery, a transmitter or apparatus for varying the resistance in circuit, and an electro-magnet placed adjacent to or surrounding the vapour tube.

The receiving circuit, as shown, consists of the tube, a suitable source of current, and a receiving device, all in series. The magnetic fluctuations caused by varying the resistance of the transmitter result in like fluctuations in the resistance of the tube, and therefore the current passing through the receiver.

It is conceivable that this device in a modified form might prove of great value in telephone work, where a thoroughly efficient repeating arrangement is wanted.

At the present time, an explanation of this peculiar effect does not appear to be forthcoming, but that the discovery is of importance, physically, if not commercially, is obvious.

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART IV.—THE ELECTRIC CIRCUIT.

By EDWIN EDSER, A.R.C.Sc.

The Magnetic Field of a Current.

WHEN the terminals of a Daniell cell are connected by a wire, the following important changes occur: Within the cell, the zinc dissolves, liberating a certain amount of energy; at the same time copper is removed from the solution of copper sulphate, and deposited on the electrode immersed in this solution, thus absorbing a certain amount of energy: the energy liberated by the solution of the zinc is, however, in excess of that absorbed by the deposition of copper, so that there is a net liberation of energy. Heat is produced in the electric circuit comprising the connecting wire and the liquid cont nts of the cell, thus disposing of the net amount of energy liberated by the chemical reaction within the cell. In the neighbourhood of the connecting wire a magnetic field is produced; if we imagine the copper electrode to the cell to be connected to the upper, and the zinc electrode to the lower end of a vertical wire, then the magnetic field consists of circular lines of force concentric with the wire, their direction being right-handed or clockwise (Fig. 1, *a*) when viewed from above. To account for the production of the magnetic field and the generation of heat in the wire, we say that an *electric current* flows through the wire. The direction of the current in the wire is defined arbitrarily as that from the copper to the zinc electrode of the cell: the copper electrode is said to be positive, and the zinc electrode negative. The connection between the direction of the current and that of the associated lines of force may most effectively be expressed as follows: Imagine a right-handed screw, fitting in a stationary nut, to be placed along the line forming the axis of the conducting wire; then the direction of the lines of force is that in which the screw must be turned, in order to make it move through the nut in the direction of the current.

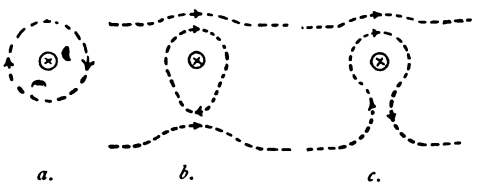

FIG. 1.—TO ILLUSTRATE THE MANNER IN WHICH THE LINES OF FORCE DUE TO A CURRENT LINK THEMSELVES ON TO THE LINES DUE TO AN INDEPENDENT FIELD.

If a conductor carrying a current is placed in an independent magnetic field, both the lines of force due to the current and those due to the independent field are modified. The small circle in Fig. 1, *b*, represents the section of a conductor carrying a current vertically downwards through the plane of the paper: the small cross within the circle represents the feathered end of an arrow travelling away from the observer, *i.e.*, in the direction of the current. Let us suppose that, in the absence of the current, the independent field would consist of parallel lines of force extending from left to right in the plane of the paper; a line of force due to the current, which would be circular and concentric with the section of the conductor in the absence of the independent field, is shown between two lines of force due to the latter. On one side of the conductor the line of force due to the current has the same direction as the neighbouring line of force due to the independent field, with the result that each repels the other; on the opposite side of the conductor the lines of force due to the current and the independent field have opposite directions, with the result that they attract each other. If we now suppose that an increase in the current causes the line of force associated with it to expand, it will touch the line of force due to the independent field where the two have opposite directions; in this case the two lines of force coalesce, in the manner previously described,* and form a single line of force bent round the conductor (Fig. 1, *c*). The reader who has followed this reasoning will find no difficulty in accounting for the shapes of the lines of

* TECHNICS, No. 10, October, 1904, p. 367.

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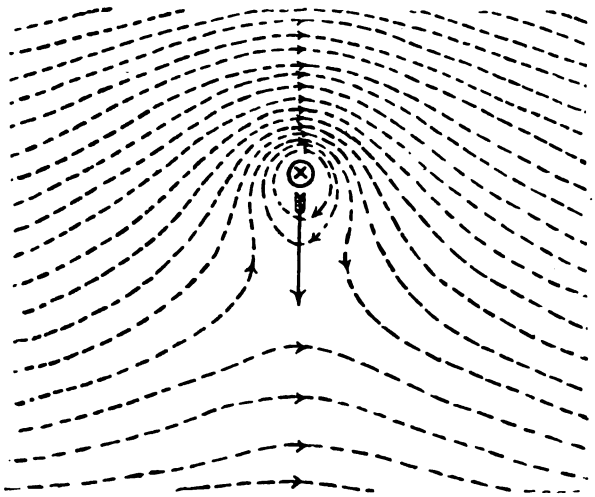

FIG. 2.—LINES OF FORCE DUE TO A RECTILINEAR CURRENT FLOWING PERPENDICULAR TO A UNIFORM FIELD.

force in Fig. 2, which represents the complete field due to a current flowing downwards through the plane of the paper, combined with a uniform field which, in the absence of the current, would consist of parallel straight lines extending from left to right.

An attentive study of Fig. 2 will show the direction of the force which acts on the conductor carrying the current. Each line of force bent round the conductor tends to contract, and so straighten out, but is prevented from doing so by the lateral repulsion between it and the lines of force which form closed curves round the conductor; consequently the conductor is acted on by a force in the direction of the arrow. It will be found that the above reasoning gives us the simplest and most easily remembered rule for finding the direction of the force acting on a conductor carrying a current at right angles to the lines of force of an independent field; *the force acts from the side of the conductor on which the two fields reinforce each other, toward the opposite side where the fields oppose each other.* The force is always perpendicular to the conductor and to the component of the independent field at right angles to the conductor. If the independent field has a component parallel to the conductor, this component can neither reinforce nor oppose the field due to the current, and therefore produces no force on the conductor.

Lines of force similar to those represented in Fig. 2 can be mapped out experimentally by the aid of a charm compass, if a current of from four to six amperes is led along a vertical wire passing through a horizontal board, on which a sheet of paper is placed. In this case the independent field is the horizontal component of the earth's field. The direction of the force acting on a conductor carrying an electric current at right angles to a magnetic field, can be verified by passing a current of about one ampere through a long piece of No. 32 wire hanging freely downwards. On bringing the pole of a bar magnet near to the wire, the direction of motion of the wire will be found to be that indicated by the above rule.

Fig. 3 represents the lines of force due to two equal currents flowing along straight parallel conductors in the same direction, *i.e.*, downwards through the plane of the paper. It will be observed that each line of force forms a closed curve; the lines of force near either conductor are nearly circular, but become distorted as their distance from the current producing them increases. Between the two conductors the lines due to the two currents have opposite directions, and the consequent attraction pulls these parts of the lines toward each other. When two lines touch, they join, and form a single loop surrounding both conductors; the tension of these lines tends to pull the conductors toward each other, so that we conclude that *there is an apparent attraction between parallel conductors carrying currents*

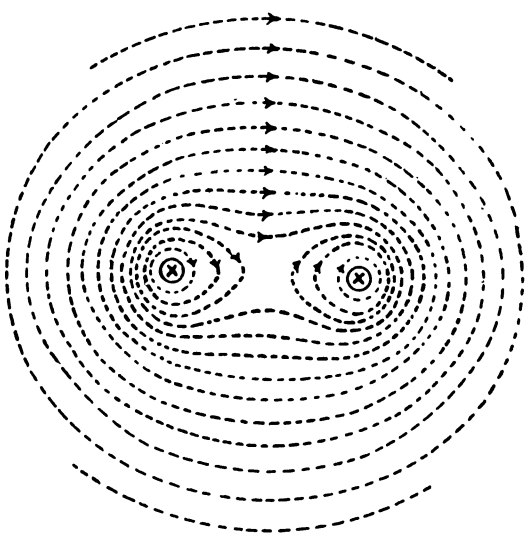

FIG. 3.—LINES OF FORCE DUE TO TWO PARALLEL RECTILINEAR CURRENTS FLOWING IN THE SAME DIRECTION.

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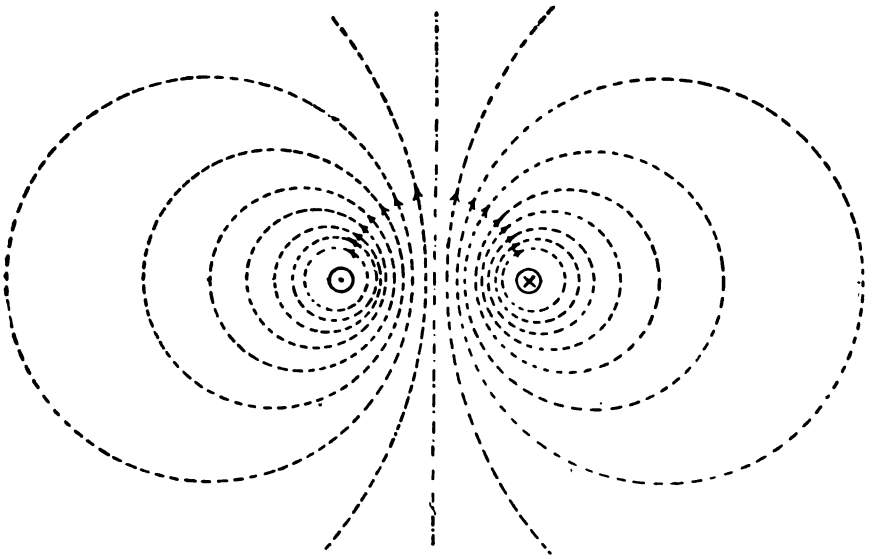

FIG. 4.—LINES OF FORCE DUE TO TWO PARALLEL RECTILINEAR CURRENTS FLOWING IN OPPOSITE DIRECTIONS.

in the same direction—a conclusion which is borne out by experiment.

Fig. 4 represents the lines of force due to two equal currents flowing along straight parallel conductors in opposite directions. The direction of the current which flows downwards through the plane of the paper is indicated by a small cross drawn within the section of the conductor: the direction of the current, which flows upward through the plane of the paper, is indicated by a small spot in the middle of the section of the conductor; this spot represents the pointed end of an arrow directed toward the observer. Between the conductors the lines of force due to both currents have the same direction, so that they repel each other, and never coalesce, as in Fig. 3; hence it is obvious that *there is an apparent repulsion between parallel conductors carrying currents in opposite directions.*

Measurement of the Electric Current.

The magnitude of an electric current is measured in terms of the magnetic field (force per unit N pole) which it produces. It is simplest to measure a current in terms of the field which it produces at the centre of a circle into which the wire carrying the current is bent; in this case all parts of the wire are at the same distance from the point at which the field is measured. It will be assumed that the magnetic field at a point can be accurately determined; the way in which this is accomplished, by observing the deflection of a magnet needle, is described in most text-books when dealing with the tangent galvanometer.

Let an electric current flow through a number of circular coils of wire, the radii of all coils being equal, while different numbers of turns of wire are comprised in different coils; then it is found that the field at the centre of any coil is proportional to the number of its turns, provided the turns lie very close together, so as to be approximately at a uniform distance from the point at which the field is measured. Hence we conclude that, with a given current flowing through a conductor all elements of which are at a uniform distance from a given point, the field at this point is proportional to the length of the conductor.

If we take a number of *equal* lengths of wire, and wind these into coils of one, two, three, etc., turns, then if the same current flows through all of the coils, it is found that the field at the centre of any coil is inversely proportional to the square of the radius of the coil. Hence we conclude that with a given current, the field at the centre of a coil—all turns of which lie very close together—will vary directly as the length l of the wire composing the coil, and inversely as the square of the common radius r of the turns; or

$$\text{Field} \propto \frac{l}{r^2}.$$

The field at the centre of a given coil of wire can be varied by inserting different

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numbers of cells in the circuit, or by varying the lengths, sectional areas, etc., of the conductors in the circuit; hence we define the magnitude C of the electric current as being proportional to the field it can produce at the centre of a given coil, so that

$$\text{Field} \propto \frac{C\,l}{r^2}.$$

We can now choose the unit of current so as to satisfy the equation—

Field at centre of coil

$$= \frac{C\,l}{r^2} \text{ dynes per unit pole} \quad . \quad . \quad . \quad . \quad (1).$$

If unit current (C = 1) flows along a conductor bent into a circle of one centimeter radius, then $l = 2\pi \times 1$; the field f at the centre of the circle will be given by the equation

$$f = \frac{1 \times 2\pi \times 1}{1^2}$$

$= 2\pi$ dynes per unit pole.

Thus we have settled on the method to be used in the measurement of an electric current, and have defined the unit of current in terms of the primary units, the *centimeter*, *second*, and *gram* (c.g.s.), or units directly derived from these primary units. The practical unit of current, the *ampere*, is one-tenth of the c.g.s. unit defined above.

Force Acting on Electric Current in Magnetic Field.

We are now in a position to determine the numerical value of the force acting on a conductor carrying a known current in a direction perpendicular to a given magnetic field. If a magnet pole is placed at the centre of a circular turn of wire, then each element of the wire will be perpendicular to the lines of force in its neighbourhood. Let the length of the turn of wire be l, while the radius of the circle is r; then if the value of the current in c.g.s. units is equal to C, the force acting on a unit (N) pole placed at the centre of the circle is given by (1) above. If a pole of strength $(+m)$ is placed at the centre of the circle, the force F acting on it will be m times as great as that acting on a unit pole, or

$$F = C\,l\,\frac{m}{r^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

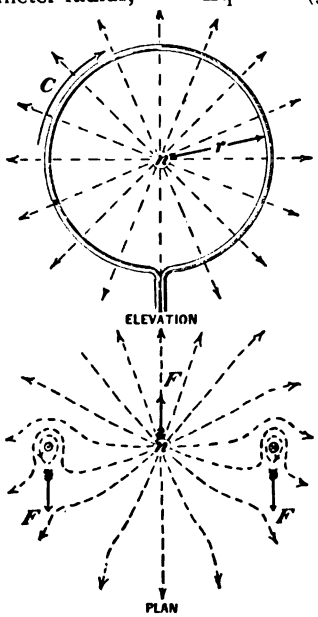

FIG. 5.—TO EXPLAIN THE NUMERICAL VALUE OF THE FORCE ON A CURRENT FLOWING PERPENDICULAR TO A MAGNETIC FIELD.

Since a force F is exerted on the magnet pole, an equal force, acting in an opposite direction, must be exerted on the turn of wire; the way in which this force is produced by the distortion of the lines of force due to the pole is plainly indicated in Fig. 5. Hence equation (2) gives the force acting on the circular turn of wire. But (m/r^2) is equal to the field, in dynes per unit pole or in lines per square centimeter,* at a distance r from a pole of strength m—*i.e.*, the field in the neighbourhood of the wire. If this field is equal to B lines of force per square centimeter, then

$$F = C\,l\,B \text{ dynes} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Equation (3) is true for any current C (in c.g.s. units) flowing along a conductor of l centimeters length, at right angles to a field of B lines per square centimeter. If the field B, instead of being perpendicular to the conductor, makes an angle θ with the perpendicular to the conductor, then the component of the field at right angles to the conductor is equal to B cos θ; and as this component is alone effective in producing a force on the conductor (p. 39), the value F of this force is given by

$$F = C\,l\,B \cos\theta \quad . \quad . \quad . \quad (4).$$

The results obtained above suffice to explain the action of an electric motor. Having given the direction of the field in the air gap, and the direction of the current in the armature conductors, the direction of rotation of the armature may be obtained by applying the reasoning given on p. 39, in connection with Fig. 2. Given the strength of the field in the air gap, the length of each armature conductor lying in this field, and the value of the current in each conductor, (3) gives us a means of calculating the force in dynes acting on each conductor.

Difference of Potential and Electro-motive Force.

When an electric current flows through a conductor, there is always some heat

* TECHNICS, No. 10, October, 1904, p. 363; and No. 12, December, 1904, p. 575.

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generated. By the Law of Conservation of Energy, this heat could not make its appearance unless some other form of energy disappeared, and in this case the energy which disappears is obviously that of the electric current. By leading a conductor through a vessel (Fig. 6) containing pure water (which is practically a non-conductor) the heat produced in a given time t by the passage of a

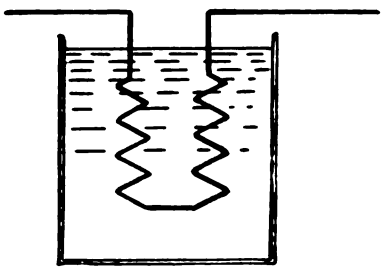

FIG. 6.—TO EXPLAIN THE P.D. PRODUCED BY THE FLOW OF A CURRENT THROUGH A WIRE.

current of C units (c.g.s.) can be determined from the mass and rise of temperature of the water; hence, knowing from Joule's investigations that one unit of heat (the heat that will raise one gram of water through 1° C.) is equivalent to forty-two million ergs of energy, we can readily calculate the amount of energy which has been changed into heat. Let this amount of energy be equal to W ergs; then we define V, the potential difference (P.D.) between the points where this energy has been dissipated, as *the energy dissipated per unit current per unit time*, or

$$V = \frac{W}{C\,t} \quad \ldots\ldots\ldots\ldots (5).$$

Thus the c.g.s. unit of P.D. is that between the ends of a conductor wherein one c.g.s. unit of current is dissipating one erg of energy per second. Since (W/t) in (5) is equal to the *rate* of dissipation of energy, or the *power* dissipated, we may define the difference of potential between two points on a conductor as the power dissipated per unit current; hence we arrive at the useful result—

$$V\,C = \text{power dissipated.}$$

The practical unit of power is the *volt*, which is equal to one hundred million (10^8) c.g.s. units. If a current of one ampere flows between two points in a circuit and produces a P.D. of one volt, the power expended is given by the equation—

(10^8 c.g.s. units of P.D.)
× ($\frac{1}{10}$ of a c.g.s. unit of C)
= 10^7 ergs per second = 1 watt.

Thus a P.D. of one volt is produced by an energy transformation proceeding at the rate of one watt per ampere.

We have as yet considered only one of the energy transformations which may occur in an electric circuit, *viz.*, that in which electrical energy disappears, its place being taken by an equivalent amount of heat. When, however, an electric current flows through a cell from the negative to the positive electrode, the net amount of energy liberated by the chemical reactions within the cell will be converted into electrical energy. Thus between two points in a circuit we may have either a *disappearance* or a *generation* of electrical energy; when electrical energy disappears between the points in question, we define the resulting P.D. as a *fall* of potential in the direction of the current: when electrical energy is generated, we define the resulting P.D. as a *rise* of potential in the direction of the current. The numerical value of the fall or rise of potential is equal to the net power lost or generated per unit current between the points.

The production of heat by an electric current is an irreversible energy transformation; by reversing the direction of the current we make no difference in the nature of the energy change, heat being produced at the expense of electrical energy in both cases. When a very small electric current flows through a cell, no appreciable amount of heat will be produced. Let a small current C flow through a cell from the negative to the positive electrode, and let the resulting chemical reactions liberate a net amount of energy equal to W ergs in t seconds; then the rise of potential is equal to $W/(Ct)$ in c.g.s. units. Faraday found that the extent of the chemical reaction is proportional to C; and as the energy W liberated is proportional to the extent of the chemical reaction, and therefore to C, it follows that the rise of potential $W/(Ct)$ in the direction of the current is independent of C. If we reverse the direction of the current flowing through the cell, we reverse the nature of the energy transformation; when the current flows through the cell from the negative to the positive electrode, chemical energy is transformed into electrical energy; when the direction of the current is reversed, electrical energy disappears, and its place is taken by chemical energy stored up in the cell. Hence, the energy transformations associated with the chemical activity of a cell are reversible. When a P.D. is the result of a reversible energy transformation it is

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termed an electro-motive force (E.M.F.). Thus we may speak of the E.M.F. between the terminals of a cell, when the current is so small that no appreciable amount of heat is produced; but if heat is produced within the cell by the current, the energy transformation becomes partially irreversible, and we may then only speak of the potential difference between the terminals of the cell.

If the terminals of a cell are merely connected by a wire, the energy liberated by the chemical reactions within the cell will be wholly converted into heat, either within the cell or in the external circuit. Let the net amount of energy liberated by the chemical reactions in a time t be equal to W; let w_1 ergs be converted into heat within the cell, and w_2 ergs in the external circuit during the same time t. Then, by the Law of Conservation of Energy

$$W = w_1 + w_2 \quad . \quad . \quad . \quad (6).$$

Let a current C be produced; then this current will have the same value in all parts of the circuit. Dividing both sides of (6) by Ct, we obtain

$$\frac{W}{Ct} = \frac{w_1}{Ct} + \frac{w_2}{Ct} \quad . \quad . \quad . \quad (7).$$

The energy W is produced by a reversible transformation, so that the left-hand side of (7) represents the E.M.F. of the cell; let this be denoted by E. The symbols w_1 and w_2 represent energy dissipated irreversibly, so that the first term on the right of (7) represents the fall of potential v_1 within the cell, while the second term represents the fall of potential v_2 in the external circuit. Thus

$$E = v_1 + v_2 \quad . \quad . \quad . \quad . \quad (8)$$

or the E.M.F. of a cell is equal to the fall of potential all round the circuit in which the cell is included.

Ohm's Law.

A conductor being given, we may determine the power per unit current dissipated when the current has various values, and so determine the relation between the current and the P.D. between the ends of the conductor. The result obtained from such an investigation is known as Ohm's law; according to this law, *if the temperature of a conductor remains constant, the difference of potential* V, *between the ends of the conductor, is proportional to the current* C; or

$$\frac{V}{C} = \text{a constant.}$$

The name given to this constant is the *resistance* of the conductor. Hence we may write,

$$\frac{V}{C} = R, \text{ or } V = C\,R \quad . \quad . \quad . \quad (9)$$

where R is the resistance of the conductor. A conductor will have unit c.g.s. resistance if a current of one c.g.s. unit flowing through it produces unit c.g.s. difference of potential between its extremities.

The *ohm* is the practical unit of resistance; if an ampere flows through a conductor with a resistance of one ohm, the P.D. between its terminals will be equal to one volt. To find the relation between the ohm and the c.g.s. unit of resistance, we have from (9)

$$\frac{10^8 \text{ c.g.s. units of P.D.}}{\frac{1}{10} \text{ c.g.s. unit of C}}$$

$$= 10^9 \text{ c.g.s. units of resistance} = 1 \text{ ohm.}$$

In connection with equation (8), let r be the internal resistance of the cell, while R is the resistance of the external circuit; then if the current in the circuit has the value C, we shall have

$$E = C\,r + C\,R = C\,(r + R);$$

$$\therefore C = \frac{E}{r + R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10).$$

This result is often quoted as representing Ohm's law; from the above reasoning it is clear that (10) is merely the result of a particular application of Ohm's law.

Induced E.M.F.

Experiment shows that when a conducting circuit is moved about in a magnetic field, under certain conditions an electric current is generated in the circuit. Now if an electric current flows in a circuit, heat must be produced; and as previously explained, this production of heat is due to the dissipation of electrical energy, so that electrical energy must be generated by moving the circuit about in a magnetic field. But for electrical energy to be generated, work of some kind must be performed; and in this case the only way in which work could be performed is in overcoming forces which oppose the motion of the circuit. Thus we arrive at an important conclusion which goes by the name Lenz's law :—*When electric currents are generated by the motion of a conducting circuit in a magnetic field, a reaction is produced which opposes the motion of the circuit.* Let us now apply the law to determine the direction of the current generated when part of a conducting circuit cuts the lines of force of a magnetic field. Fig. 7 represents a frame-

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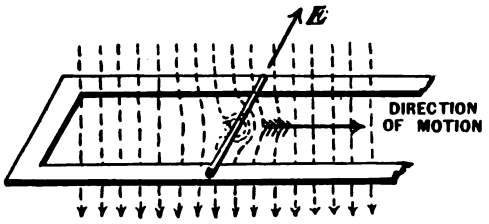

FIG. 7.—TO EXPLAIN THE PRODUCTION OF AN E.M.F. IN A CONDUCTOR WHICH IS MOVED SO AS TO CUT LINES OF FORCE.

work composed of two parallel conducting rails permanently connected at the left-hand ends, but unconnected and extending indefinitely toward the right. Let lines of magnetic force pass vertically downwards through the space between the rails, the number of lines per square centimeter being constant over the space. If a conducting rod is laid transversely across the rails, and moved at right angles to its length, either to the right or the left, then experiment shows that an electric current will be generated in the closed circuit, composed of the rod, the portions of the rails to the left of the rod, and their permanent connection. Let the direction of motion of the rod be toward the right; then the current flowing along the rod must react on the lines of force due to the field, so that the motion of the rod is opposed; and for the field to oppose the motion of the rod, its lines must be bent round in front of the rod, as shown in Fig. 7. The way in which each line of force in turn gets bent round the front of the rod, to ultimately join up behind it, leaving a line of force looped round the rod, will be sufficiently obvious from an inspection of Fig. 7. On comparing Figs. 2 and 7, it is seen that the current must flow along the rod in the direction of the arrow marked E. It will be noticed that, in moving the rod toward the right, the area of the closed circuit to the left of the rod is increased, and therefore the number of lines passing downwards through the circuit is increased; looked at from above, the current will flow round this circuit in a left-handed or anti-clockwise direction. *Thus if we increase the number of magnetic lines of force which pass through a closed conducting circuit, the current generated will flow round the circuit in an anti-clockwise direction when viewed along the direction of the lines of force.* If we decrease the number of lines of force passing through the circuit, the current produced will circulate in a clockwise direction when viewed in the direction of the line of force.

Further, since electrical energy is being generated by the motion of the rod (Fig. 7), an E.M.F. must be produced. We can now find the value of this E.M.F. in a very simple manner. The E.M.F. (in c.g.s. units) is equal to the power in ergs per second for each c.g.s. unit of current. Thus if E is the value of the E.M.F. and C is the value of the current,

E C = power developed, or work performed per second.

Let the uniform velocity of the rod toward the right be equal to v centimeters per second, and let the force opposing the motion of the rod be equal to F dynes; then the work done per second by the agent moving the rod is equal to F v ergs, and since this work must be equal to the electrical energy generated, we have

$$E C = F v \quad \ldots\ldots\ldots \quad (10).$$

Let the perpendicular distance from rail to rail be equal to l; then this will be the length of that part of the rod which is generating the E.M.F. Let the field which the rod cuts be equal to B dynes per unit pole, or lines per square centimeter; then the force F opposing the motion of the rod will be that due to a current C flowing along a conductor of length l perpendicular to an independent field B; the value of F is given in equation (3), p. 41. Substituting in (10), we obtain

$$E C = B l C. v;$$
$$\therefore E = B l v \quad \ldots\ldots\ldots \quad (11)$$

Equation (11) gives the E.M.F. generated by the motion of the rod, in c.g.s. units; to obtain it in volts we must divide by 10^8. Now as the rod of length l moves toward the right through a distance of v centimeters, it will cut through all the lines of force passing vertically through an area of $l v$ square centimeters, *i.e.*, it will cut through B $l v$ lines of force, since B lines pass through each square centimeter. Thus the E.M.F. *is equal to the number of lines of force cut per second, or the number of additional lines enclosed in the circuit per second.*

In the above investigation it has been assumed that the lines of force are perpendicular to the rod, and also to the direction of motion of the rod; it will now be shown that the same result applies whatever may be the direction of the lines of force. In Fig. 8, let A B be the rod, of length l, moving vertically downwards through the plane of the paper; and let the lines of force which the rod is cutting be parallel to the plane of

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the paper, but make an angle θ with a line drawn perpendicular to the rod and to its direction of motion. If B is the resultant value of the field, the component of B perpendicular to the rod will be equal to B cos θ, and this component is alone operative in producing a force on the conductor carrying the current C. Then, using equation (4), page 41, we shall have

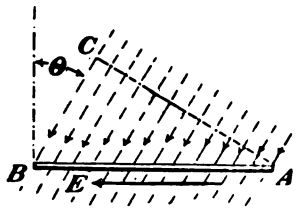

FIG. 8.—CONDUCTOR CUTTING LINES OF FORCE.

$$E C = F v = (B \cos l C) v.$$
$$E = B (l \cos \theta) v.$$

Draw the straight line A C (Fig. 8) perpendicular to the lines of force, so as to cut the same lines as are cut by A B; then A C = $l \cos \theta$; and since A C, in one second, will sweep out a rectangle of area ($l \cos \theta$) × v square centimeters perpendicular to the lines of force, B ($l \cos \theta$) v will be the number of lines cut per second by the line A C, which is equal to the number cut by the rod A B.

The results already obtained give us the means of solving, in a very simple manner, a problem which will subsequently be found of considerable importance. This problem is as follows:—A current C flows along a straight conductor of great length; it is required to find the field (force per unit N pole) at a distance r from the conductor, when r is small in comparison with the length of the rod. It is supposed that, in the absence of the field due to the current, there would be no lines of force in the neighbourhood of the conductor, so that the field to be determined is that merely due to the current.

Let a unit N pole n (Fig. 9) be placed at a distance r cms.

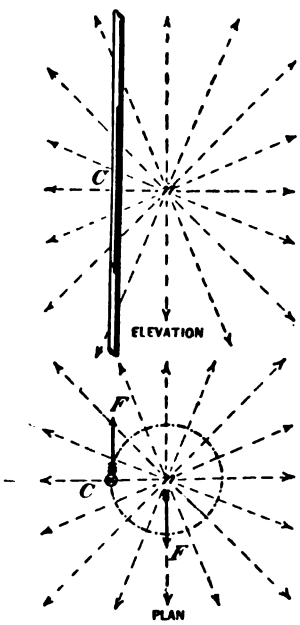

FIG. 9.—TO EXPLAIN HOW THE FIELD AT A GIVEN DISTANCE FROM A RECTILINEAR CURRENT MAY BE DETERMINED.

from the long straight conductor carrying the current C (c.g.s.); then if F is the force in dynes acting on the unit N pole, an equal and opposite force must act on the conductor (see Fig. 9, plan). If we move the conductor round the unit N pole, at a uniform distance r from this, the work done will be equal to F × $2\pi r$ ergs. The conductor will cut the lines (or tubes) of force due to the pole, and so generate an E.M.F.; if the direction of motion is anticlockwise in the plan (Fig. 9), the E.M.F. will be in the direction of the current C, and if the conductor is moved at the requisite speed, we may produce such a value of E as will generate a current C in the circuit of which the conductor forms part. In this case C is produced merely by the motion of the conductor. Let t seconds be required for a revolution of the conductor about n; then the electrical energy generated = E Ct ergs.

Equating this to the work performed, we have

$$EC t = 2\pi r F \quad . \quad . \quad . \quad (12)$$

E will be equal to the total number of tubes of force cut per second by the conductor; when the conductor is very long in comparison with r, it will, during one revolution (*i.e.*, in the time t), cut practically all the tubes of force diverging from n.

Hence E = $(4\pi \times 1)/t$. Substituting in (12), we have

$$\frac{4\pi}{t} C t = 4\pi C = 2 r F;$$

$$\therefore F = \frac{2C}{r} \quad . \quad . \quad . \quad (13).$$

Thus the field (force per unit N pole) at a distance r from a very long straight current C is equal to 2C/r.

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THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C., Chemical Engineer and Consulting Chemist, Manchester.

WE have mentioned before that one of the principal points to be considered in the construction of an evaporating plant is that the products of combustion should be used to the greatest advantage—that is, that the greatest surface of the evaporating vessel should be exposed to their action. It would also follow that the surface of the vessel should be a maximum with regard to its volume. It must have struck the student who has a fair knowledge of mathematics that the instances which we have given so far are theoretically not adapted to fulfil these conditions. It is well known that the half-section of a sphere offers the least surface with regard to its volume. It would be possible to increase the ratio between surface and volume by making the pot shallower, but it would then be more difficult to build a flue round it. It is evident that there is no reason why evaporating vessels of a different shape should not be used; for instance, one which resembles a bath, such as is used for domestic purposes, or a cylinder cut in two. The latter would give more surface in proportion to its length. If, for instance, the length were four times the radius of the corresponding cylinder, we should gain 20 per cent. in surface, as compared with a half-sphere of equal volume; if it were eight times longer than the radius, we should gain 36 per cent. As the flues follow straight lines instead of curves, they will be easier to build, easier to clean, and more economical to construct.

Figs. 7 and 8 represent such an arrangement.

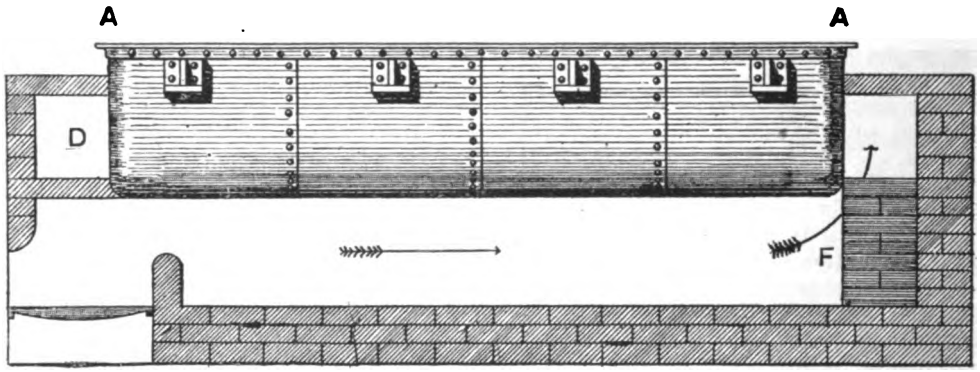

FIG. 7.—SIDE ELEVATION OF SEMI-CYLINDRICAL EVAPORATING VESSEL.

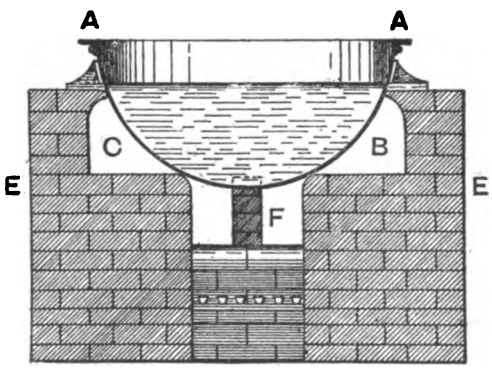

FIG. 8.—TRANSVERSE SECTION OF SEMI-CYLINDRICAL EVAPORATING VESSEL.

The pan AA, which in this case is made of wrought iron, rests on the brick walls EE. The fire-gases travel underneath the pan, then upwards, are divided by the pillar F, then pass through the right and left flues B and C simultaneously, join up again in the front at D, and are taken from this into the main flue. Dampers are provided in the flues B and C to regulate the draft in each of the side flues, in case it should be stronger on one side than it is on the other. The question will be asked: Why not always use a long pan? The answer to this will be apparent if the student will make a drawing for himself of a pot and of a pan, the length of the latter being eight times the radius of

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the corresponding cylinder, each capable of holding 100 gallons. He will then notice that for small quantities of liquid there is no advantage in a long pan, as the side flues become very shallow, and as the surface can thus not be utilised to its best advantage in economising heat. The question of cost of plant will also often determine the shape of the evaporating vessel; for whilst, weight for weight, cast iron is cheaper than wrought iron, vessels made of the former have to be constructed in much thicker metal, and therefore may become more expensive than wrought iron apparatus, always provided that in the latter the cost of shaping and rivetting is not excessive. A small cast iron pot may be cheaper than a wrought iron pan; and a large cast iron pan may be dearer than a pot or pan made of wrought iron.

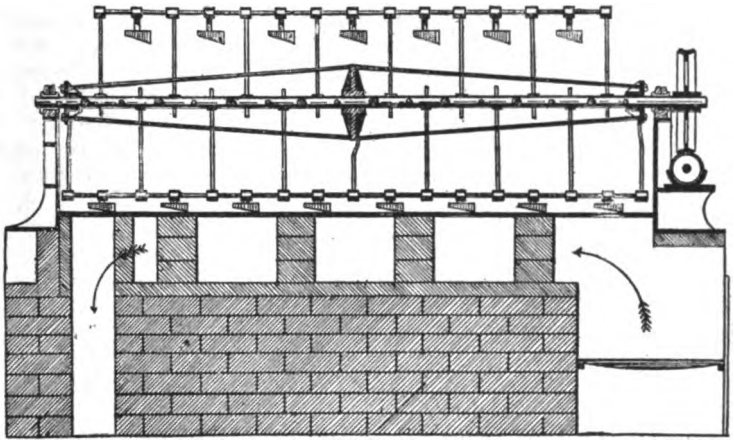

FIG. 9.—SIDE VIEW OF THELEN PAN.

In the boiling down of solutions, it often happens that solid matters separate out, and settle on the sides of the evaporating vessel. The crusts which are thus formed are dried by the heat of the flue gases, and being in every case worse conductors of heat than iron, or metal of other description, prevent the heat from passing to the liquid, and thus doing its work economically. In consequence of this, the evaporating vessel becomes unevenly heated, partially to a much higher temperature than would otherwise be required, and is apt to alter its shape or to burn through in those places where, being encrusted, it is exposed to the greatest heat. It is, therefore, in many cases advisable to have a mechanical arrangement which keeps the sides of the evaporating vessel free from incrustations. This purpose may be effected by means of an agitator, the arms of which are arranged in such a manner that they traverse every part of the sides of the pot. A better arrangement would be one which would at the same time remove the precipitated matter altogether from the liquid, and such a design is shown in Figs. 9 and 10, and is known by the name of a Thelen pan.

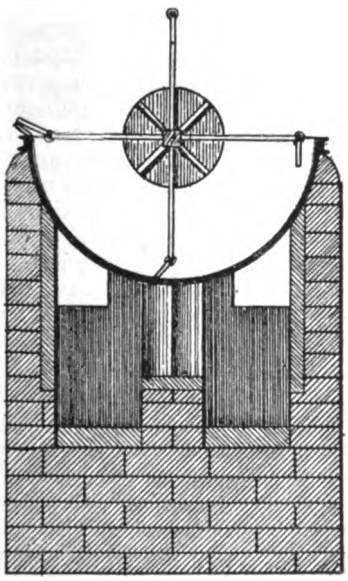

FIG. 10.—TRANSVERSE SECTION OF THELEN PAN.

The pan is similar to the one described last. A shaft works in bearings at each end and is provided with arms, each carrying a little movable shovel at its end. The arms are arranged in such a manner that the little shovels move any deposit towards the end of the pan, and the sediment on arriving there is taken up by another shovel and lifted bodily out of the pan into a draining vessel, from which the liquor can drain straight back into the pan. Several of these pans may be coupled together, so that the waste heat from one pan heats the succeeding one.

A natural consequence of the foregoing remarks, and which no doubt will readily occur to the student, is that an evaporating pan should always be filled with liquor above the highest point of the surrounding flues, otherwise these parts would become overheated, and would soon deteriorate.

In the apparatus which we have so far

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described, the liquor to be concentrated has been placed in a suitable vessel, and the fire gases produced from the combustion of fuel have been passed under and round the vessel, without coming into contact with the liquor which is to be evaporated. But an arrangement could be designed by which the products of combustion would be passed over the surface of the liquor which has to be concentrated. Such an arrangement is occasionally used, but it has the great drawback that naturally the liquor becomes contaminated with dust and objectionable impurities, such as sulphurous acid, which is almost always present in the products formed by the combustion of coal. This device is therefore not very often used, though it is possible that, with the extension of gas for fuel, it may be found useful in certain cases in which it has not been applied so far.

We have now considered such constructions of evaporating vessels which closely resemble the laboratory processes in which a Bunsen burner is placed under a beaker or dish filled with liquid. It is often found more advisable in laboratory work not to use the naked flame for these operations, but to use a water, sand, metal, oil or air bath, in order to obtain lower or higher and fairly constant temperatures. Where similar results have to be obtained on a large scale, there should be no difficulty to the student, after the preceding remarks, to elaborate arrangements of this kind suitable for technical work; bearing in mind all the time, that in working on a large scale, he has an important auxiliary in steam, which, with few exceptions, chiefly found in experimental dye-houses, is not to any great extent made available in college laboratories. As a matter of fact, it is much more difficult to put together a small laboratory apparatus with closed-in steam than it is to construct a large apparatus in the works. As steam can be produced at different pressures, and consequently at different constant temperatures; as it can, moreover, be superheated to still higher temperatures than those which belong to it at its relative pressure, we have a ready means of producing and maintaining constant temperatures ranging from 100° Centigrade to about 400° Centigrade.

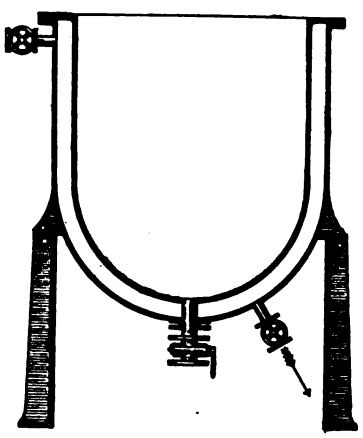

FIG. 11.
STEAM-JACKETED VESSEL.

Where a sand-bath, oil-bath, or metal-bath is used, the arrangement will be almost identical with the one which is used for the purpose in the laboratory. If we use vessels of pot shape, it will be only necessary to place one pot into another of a larger size, and fill in the empty space between the two with either sand, oil, or lead, or any alloy which will give the required temperature. When steam is used, a similar arrangement may be resorted to, but with this difference, that the two pots will have to be jointed together steam-tight. Such an arrangement is shown in Fig. 11.

It is necessary to let the steam enter at the top, and to remove the condensed water and superfluous steam at the bottom, so as to give the waste steam and water a free passage. In order to use the steam most economically, it is necessary to take care that no more steam is used than will conveniently condense, so that only hot water may leave the apparatus. This may be either used for feeding the boiler, or for other purposes where hot water is required, or it may be taken through suitable coils placed in the liquid which feeds the boiling down pan, and thus serve to give that liquid a preliminary heating.

In constructing jacket pans, care must be taken to make sufficient allowance in the strength and shape of the vessels to stand the pressure of the steam; and it will in many cases be found advisable to make the surrounding or outside jacket of wrought iron, which will resist a greater amount of pressure for the same thickness of metal than cast iron. All apparatus of this kind, in fact all apparatus which has to stand exterior or interior pressure, should be designed so as to present as little surface of a plane shape as possible; all surfaces should represent curves. This precaution need not be taken if we pass the steam through a coil placed in a suitably shaped evaporating vessel; in that manner the initial expense is reduced, and as it is possible to obtain welded coils of wrought iron of almost any shape, vessels of different material, and of pot, pan, or box shape may be used, in conjunction with steam-heating coils. The objection to coils is that they are troublesome to keep clean where solids are apt to be deposited, and when covered

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with incrustation they become inefficient. An ingenious device has been resorted to to overcome this objectionable feature, and one which combines the advantages of a jacket and coil pan. It has been found possible to cast molten iron round coils of wrought iron pipes, so that a cast iron vessel may be obtained, which can be heated by steam passing through the sides which define its shape. Fig. 12 shows such an arrangement, which requires no further explanation.

Care should be taken in all cases to prevent radiation from the evaporation vessel as much as possible, and this is done by either surrounding it with several courses of brickwork, or by coating it with compositions which have little conductivity for heat, such as the well-known compositions which are used for steam boiler coverings. In using coils for evaporating purposes, there is one point which must be particularly watched. If steam is passed through a coil which is slightly leaking, two things may happen: the steam may escape into the surrounding liquid and cause unnecessary dilution, or the surrounding liquid may be drawn through that fine opening, and in that way loss may be caused. Wherever a coil is used for evaporating purposes, it is, therefore, necessary to test the condensed water from time to time, to see that it is free from any of the substance which is placed in the boiling down vessel.

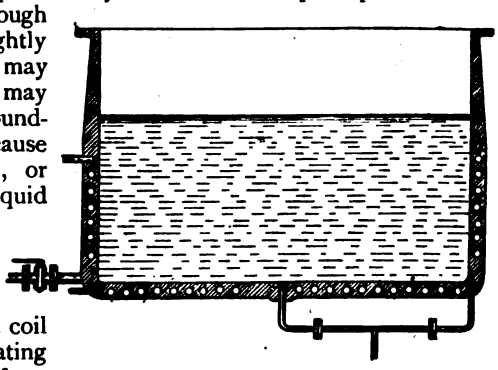

FIG. 12.—STEAM-JACKETED BATH.

In special cases it will be found that the waste steam from the steam engines may be utilised for evaporating purposes, and wherever this is possible it should be done. We shall have occasion to refer to this again.

We have so far only dealt with the commonest forms of apparatus for evaporation, not only for the reason that they are used more extensively than others, but because they illustrate most clearly the principles on which such apparatus is constructed. In the space at our disposal, it is impossible to deal with every kind of known apparatus, and it will occur to the student who has already a fair knowledge of chemical technology that special modes of evaporation, such as brine towers, the Glover towers, and others, of which he is cognisant, have not been mentioned. All kinds of apparatus may be, and have been, constructed for special purposes, but there is no necessity to describe every one in detail. They are all based on the principles which we have explained: that is, to give as much surface to the evaporating liquor as possible and to use up waste heat. The aim of technical education should not be to produce a specialist who can at once take charge of a special line of manufacture, and who is conversant with all the little details which have been acquired in the course of many years by each manufacturer; for that reason we restrict our remarks in these articles to such general explanations of the principles of chemical engineering as will enable the student to realise, as occasion may arise, why certain apparatus may or may not be the most suitable for special purposes, and that he may in each case be able to judge how far any special apparatus may be right in principle and detail, and for what reason it has been constructed on its characteristic lines.

Cases arise in which the vapours evolved from the boiling liquids have to overcome a greater pressure than that of the atmosphere, or in which the pressure under which they are evolved is smaller than that of the surrounding atmosphere, *i.e.*, 15 lbs. per square inch. These cases may be considered as processes of evaporation or of distillation, for no hard-and-fast line can be drawn between the two. For our purposes it will be most convenient to treat all processes of evaporation which take place in a closed system as processes of distillation, and thus include in that category evaporation under increased or diminished pressure. Taking that view, we will now proceed to the next chapter, in which we shall deal with apparatus used for distillation and condensation, including the important subject of evaporation in a vacuum.

Distilling Flasks, Liebig Condensers, Fractionating Tubes and their Technical Equivalents.

We have mentioned above that evaporation may be carried on either under increased or diminished pressure. Practically speaking, all the apparatus which has been described so far for evaporating can be easily converted into part of an apparatus for boiling down under a pressure, or in a vacuum, by simply

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putting a lid on the top of either the pots, or pans, which we have described before. We shall deal with the evaporation under pressure later on, when we shall describe the construction and function of a steam boiler. Before describing the form of apparatus which is used for evaporation in a vacuum on a manufacturing scale, we will consider the apparatus which is used in the laboratory for similar purposes

(To be continued.)

THE SCINTILLOSCOPE.

THE scintillations of a zinc sulphide screen, when a particle of radium is placed near it, were first observed by Sir William Crookes, who invented the instrument called the Spinthariscope. The minute flashes of light are produced by the α rays impinging on the sulphide; whether each α ray particle produces a separate scintillation, or whether the scintillations are due to cleavage of the sulphide crystals, brought about by the cumulative effect of the bombardment of α rays, is at present a disputed point. However, it is certain that the α rays possess little penetrating power; they cannot even pass through a sheet of paper. Consequently, to observe the scintillations of a screen formed on an opaque sheet, it is necessary to place the radium on a small metal disc between the screen and the eye, and this disc naturally hides the brightest part of the screen.

THE SCINTILLOSCOPE.

This difficulty has been avoided in the Scintilloscope by using a transparent screen coated on one side only. In this way the radio-active substance can be brought very near to the fluorescent salt, so as to obtain maximum luminosity, which may be observed through the transparent screen. The relative transparency of various substances can be directly studied by the aid of the Scintilloscope. Very thin films of gold and silver, mica and celluloid, transmit Alpha rays; they will pass through several pieces of aluminium foil or thin tissue-paper. The rays which do get through still produce the scintillations which are characteristic of Alpha rays. If the luminous screen is now examined by the aid of a lens, a very beautiful spinthariscopic effect is seen; if polonium is used instead of radium, the effect is still more beautiful, since the polonium emits α rays only, and therefore there is no general illumination of the screen; the sparkling light appears on a perfectly dark background.

It has been found that, by the aid of the Scintilloscope, even the effects produced by the α rays emitted from Joachimsthal pitchblende can be observed. With care, luminous effects can be observed from metallic uranium, thorium compounds —even a Welsbach mantle will do the same, but the eye must be thoroughly well rested before the attempt is made. Thus the Scintilloscope rivals the electroscope as a detector of α rays.

The Scintilloscope is made by its inventor and patentee, Mr. F. Harrison Glaw, of 156, Clapham Road, London, S.W.

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BEATING-UP IN POWER LOOMS AS A MECHANICAL PROBLEM.

By A. CRABTREE, Lecturer on "Cotton Weaving" at the Todmorden and Hebden Bridge Technical Schools.

THIS is one of the most interesting of the mechanical problems connected with the power loom, and although it is essentially a theoretical problem, it is by no means lacking in practical utility. Notwithstanding this, no very great amount of attention appears to have been given to the matter, and it is still, to a great extent, misunderstood by those interested in weaving machinery.

In nearly all text-books on weaving, the subject is treated as if the slay were a freely moving body, and the only solution usually attempted is embodied in the statement that "the force available for beating-up varies as the square of the velocity of the slay." If the assumption that the slay is a freely moving body were accurate, this would no doubt be perfectly correct, and would be quite satisfactory. The assumption is, of course, not accurate, the motion being governed in a perfectly definite manner by the crank and crank arm; and consequently other forces are brought into play which completely alter the nature of the problem.

The character of the motion of the slay is well known, and has been dealt with in a very able manner, in at least two books on cotton weaving, so that it is unnecessary to go into this part of the subject here.

In studying the forces acting on the slay, it is necessary to have a clear idea of the changes which take place in the velocity. Perhaps the best method of showing these changes is by means of curves, as shown in Fig. 1. In this diagram the position of the crank may be read off on the horizontal axis, and the velocity of the connecting pin on the vertical axis.

In order to give additional interest to the diagram, three cases are worked out, which show clearly the effect of different lengths of crank and crank arm on the velocity of the connecting pin.

The first case is the simple harmonic curve, showing the velocities due to the crank alone, such as would be obtained by the use of an infinitely long arm. In such a case as this, the velocity of the connecting pin can be obtained from the formula

$$\text{Velocity of connecting pin} = \text{velocity of crank pin} \times \sin\theta.$$

In this formula and all succeeding ones θ = the angle of the crank measured from the front centre.

The two remaining curves show the effect of using different lengths of crank arm, giving varying degrees of eccentricity. The formula for obtaining the velocity in these cases is somewhat more intricate :—

$$\text{Velocity of connecting pin} = \text{velocity of crank pin}\left\{\sin\theta + \frac{c \times \sin\theta\cos\theta}{\sqrt{a^2 - c^2\sin^2\theta}}\right\}$$

In this formula c = length of crank and a = length of crank arm. In order to obtain definite figures, the speed of loom is taken as 200 picks per minute, and the length of crank two inches in each case. From these particulars we get

$$\text{Velocity of crank} = \frac{200 \times 4 \times 3{\cdot}1416}{60 \times 12} = 3{\cdot}5 \text{ feet per second.}$$

The formula now becomes

$$\text{Velocity of connecting pin} = 3{\cdot}5\left\{\sin\theta + \frac{2 \times \sin\theta\cos\theta}{\sqrt{a^2 - 4\sin^2\theta}}\right\} \text{feet per second.}$$

Supposing, for example, we require the velocity of the connecting pin when the crank is at an angle of 30° from the front centre, assuming the loom to have an eight-inch crank arm (curve 3) :—

$$\text{Velocity of connecting pin} = 3{\cdot}5\left\{\sin 30^\circ + \frac{2\sin 30^\circ\cos 30^\circ}{\sqrt{64 - 4\sin^2 30^\circ}}\right\}$$

This gives

$$3{\cdot}5\left\{{\cdot}5 + \frac{{\cdot}866}{\sqrt{63}}\right\}$$

which works out to 2·1315 feet per second.

The velocities at other points may be obtained in the same way, and finally the curve filled in, showing the velocities at intermediate points.

On examining these curves, it will be seen

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that in all cases the speed of the slay increases rapidly from back centre to a point at or near the top centre, after which the speed decreases. From this it follows that force must be acting on the slay, to increase the velocity during the first half of this movement, and force must be acting in the opposite direction, to decrease the velocity during the second half.

The force which is exerted to increase the velocity is, of course, supplied by the crank, that is, indirectly, from the belt driving the loom; whilst the retarding force comes from whatever there may be resisting the forward movement. This important point will be returned to later.

Definite values can be readily given to these forces, if we take definite dimensions of parts and definite speeds.

The relation of force to velocity and weight is expressed in the following formula—

$$\text{Force in lbs.} = \frac{w \cdot a}{g}$$

In this formula w = weight in pounds, a = acceleration in feet per second per second, g = 32 ft. per second per second.

The force is therefore proportional to the weight of the slay, and also to the rate of acceleration, or the rate per second at which the velocity is changed.

To apply this, however, the rate of acceleration must be known, and it is evident, from the shape of the curves in Fig. 1, that this rate will vary throughout the movement.

Perhaps the simplest method of obtaining the rate of acceleration at any point is to obtain the exact velocity of the slay at each of two points, say one degree apart on the crank circle. Subtract one from the other. This gives the increase or decrease of velocity per degree, or in other words, the acceleration per degree.

By finding the rate of acceleration at different points in this way, a second series of curves (Fig. 2) can be obtained, showing the varying rate of acceleration. The acceleration per degree may be readily converted into acceleration per second.

For example. Take a point where the acceleration is ·05 feet per second per degree. From this we get

$$\frac{\cdot 05 \times 360 \times 200}{60} = 60 \text{ feet per sec. per sec.}$$

The rates of acceleration are marked on the diagram (Fig. 2) both per degree and per second.

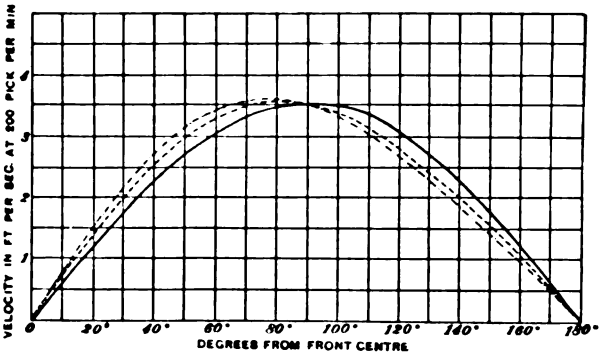

FIG. 1.—TO SHOW THE VELOCITY OF SLAY AT EACH POINT FROM BACK-CENTRE TO FRONT-CENTRE.

Curve ———— Infinite arm, 2-inch crank.
Curve - - - - - 12-inch arm, 2-inch crank.
Curve - · - · - · 8-inch arm, 2-inch crank.

On examining these curves, it is at once evident that the slay starts from the back with a high positive acceleration, which gradually diminishes until near the centre the velocity is uniform; after which the acceleration becomes negative, or in other words, it becomes a retardation. It has been pointed out above, that the force is proportional to the rate of acceleration. This being so, the curves of acceleration may be taken as curves of force; a positive acceleration represents a force tending to move the slay forward, and a negative acceleration represents a force tending to arrest the forward movement.

If we take, as an example, a definite weight of slay, say 64 lbs., we get definite values for these forces.

Thus, $\text{Force in lbs.} = \frac{w \cdot a}{g}$.

This gives

$$\text{Force in lbs.} = \frac{64 \times a}{32} = 2a.$$

Thus with a 64-lb. slay the force in pounds is exactly twice the rate of acceleration in feet per second per second. These forces are marked on the diagram (Fig. 2), and represent the forces acting on the connecting pin. If the curves are examined from this point of view, it is evident that during the first half of the movement a gradually decreasing force is applied by the crank, whilst during the latter half, a gradually increasing force is exerted against the motion of the slay, by whatever there may be resisting its forward movement. The latter part of this statement might be put as follows:—An increasing force is exerted by the slay on whatever is resisting its forward movement.

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On what is this force exerted? Evidently, if the loom were running without warp or weft, it could only be exerted on the crank, on which it would be exerted as a forward pull, tending to move the loom faster, or in other words, helping to drive the loom. In this way the energy expended in raising the speed of the slay in the first half of the movement is given out again in the second half, less a certain amount of loss due to friction. If the loom is actually weaving cloth, a certain amount of force is exerted in pushing forward the weft and overcoming the friction of the threads. This is the actual force exerted in beating-up, and will vary according to circumstances. It would be difficult, if not impossible, to estimate this, owing to lack of sufficient data. In light goods it will be very small, whilst in heavy goods it may be considerable at or near the front centre. It is not, however, so important that we should know exactly what force is actually exerted in pushing forward the weft, as it is that we should know what force is available for doing this under different conditions.

It has been shown above that there is a certain amount of force due to the retardation from top to front centre, which is available for the beat-up. It is shown in Fig. 2 that this force, in one of the cases taken, amounts to about 180 lbs. near the front centre (neglecting the difference between the motion of pin and reed). Is this the solution of the problem? It would certainly be the solution if the only force available were that due to the kinetic energy stored up in the moving slay. A moment's consideration will show that it is not, however, the maximum force available. Supposing for a moment that the force required to beat up the weft were to exceed the 180 lbs., what would happen? If this were the only force available, the loom would be stopped at once. This, however, would not be the case by any means. Instead of this, more power would be drawn from the belt, so that instead of the slay pulling at the crank, as it would do at this point in a loom running without warp, it will be pushed forward by the crank.

The total force available for beating-up is, therefore, not simply that due to the kinetic energy of the slay, and proportional to the square of the velocity, as would be the case if the slay were a freely moving body, but is only limited by the driving capacity of the belt. From these deductions, it might be expected that a slowly moving slay will weave as heavy a cloth as a quickly moving one. This, however, is proved by experiment and practical experience not to be the case, and the reason is probably as follows. In the case of the slowly moving slay, the force acts on the cloth gradually, and when the force reaches a certain point the warp is drawn from the beam, the cloth being pushed forward.

With the quickly moving slay, a considerably higher force may be exerted without the beam being turned, owing to the greater suddenness with which the force is applied. This is due to the inertia of the warp beam and parts connected to it. This effect is precisely the same as the moulding of a cylindrical lead bullet to the bore of a rifle, when fired with quick-burning powder from a grooved rifle. The bullet is expanded by the force of the explosion, before its inertia is overcome and it starts moving.

If slow-burning powder is used, there is no such action, owing to the more gradual application of the force. From this it appears that the capacity of a loom for weaving heavy cloth really does depend, to a great extent, on the velocity of the slay at or near the front centre, but this is not due to the reason usually assigned to it. Another important point in the equipment of a loom for very heavy work is evidently the weight of the warp beam; the heavier the beam, and the more heavily the beam can be weighted, the heavier will be the cloth which can be woven

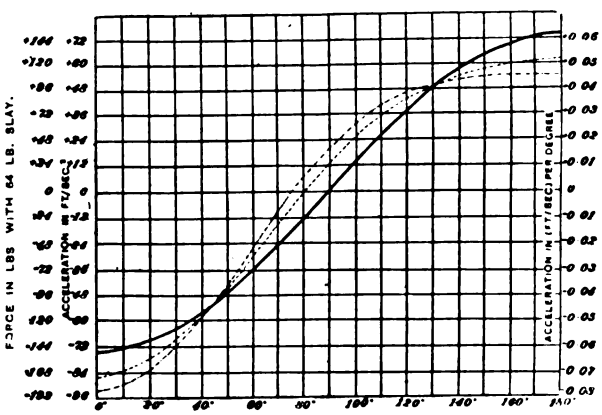

FIG. 2.—TO SHOW ACCELERATION, AND ALSO FORCE EXERTED ON AND BY SLAY AT DIFFERENT POINTS.

Curve ——— *Infinite arm, 2-inch crank.*
Curve - - - - - 12-*inch arm, 2-inch crank.*
Curve - · - · - 8-*inch arm, 2-inch crank.*

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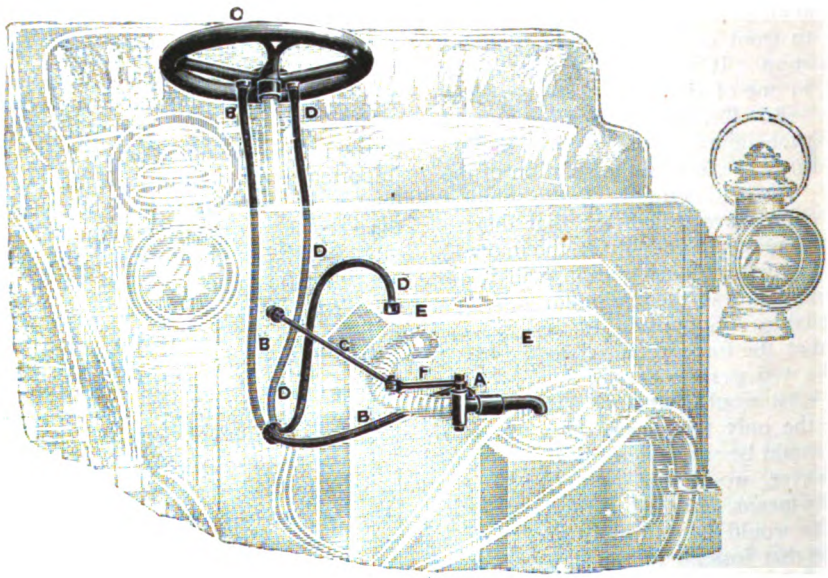
in a given loom. Better still, a positive let-off motion might be used, in which case it would appear that the number of pick which could be inserted would only be theoretically limited by the strength of the warp. The above remarks apply chiefly to very heavy work. In weaving light goods, the conditions are altogether different, and it is quite evident that very little force is necessary, the weft being simply pushed forward into its proper place, against very little resistance.

In such a case, high speed and weight are of no importance, so far as force of beat-up is concerned; also no great strength of parts is necessary.

Much might be said in favour of the American plan of using wood to some extent, in the construction of light looms; as for example, slay swords and crank arms. At any rate, this is a point worthy of attention from our loom makers.

This article has been written with a view to throwing some light on the nature of the forces acting on the slay. Many interesting points connected with "beating-up" have been neglected, as not being essential to the solution of the particular problem referred to

DEVICE FOR HEATING MOTOR CAR STEERING WHEELS.



THE above illustration explains a device (due to Mr. R. W. Coan, of 219, Goswell Road, E.C.) for heating the steering wheel of a motor car by means of water which has been used to cool the cylinder of the motor. A gun-metal cock A is connected to the circulating pipe, and is provided with a branch piece to which is attached the tube B. The hot water from the cylinder jacket can thus be intercepted, and instead of passing direct to the tank, is made to pass through the tube B into the hollow steering wheel C, returning through the tube D into the cooling tank E. The cock is worked by the lever F, to which is attached a rod G, passing through the dash-board, and within easy reach of the driver's hand.

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EPICYCLIC TRAINS.

By THORNTON KNOWLES.

IN most cases where toothed gearing is employed, the wheels in gear with each other rotate, while the frame supporting them remains stationary. If, instead of the frame being fixed, one of the wheels constitutes the fixed link, the frame being permitted to revolve round the axis of the fixed wheel, we obtain an epicyclic train. Such a train is capable of producing a high velocity ratio with the employment of a very few parts.

The simplest case is that shown in Fig. 1, in which two wheels A, B are in gear and connected by a link C. If the wheel A be fixed and the link C rotates, the motion of the wheel B will be the resultant of two components—that of its own motion relative to the link C, and that of the motion of the link C

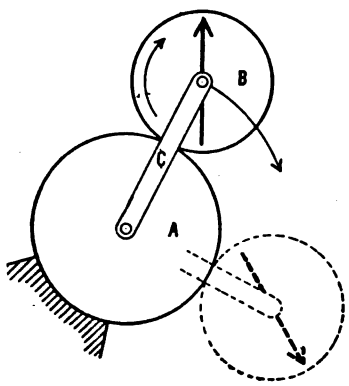

FIG. 1.

relative to the fixed wheel A. In any case where two bodies have motion relatively to a third which is fixed, the angular movement of the first to the third is the algebraic sum of the relative angular movements of the first to the second and the second to the third. The angular movement of the wheel B with regard to the wheel A is, therefore, the algebraic sum of the angular movements of the wheel B relative to the link C, and of the link C to the wheel A. If N be the velocity ratio of the two wheels, for one revolution of the arm C in a clockwise or positive direction the wheel B will have moved + N revolutions relative to the arm, and the arm will have moved + 1 revolution with regard to the fixed wheel A, making

B's revolutions = 1 + N.

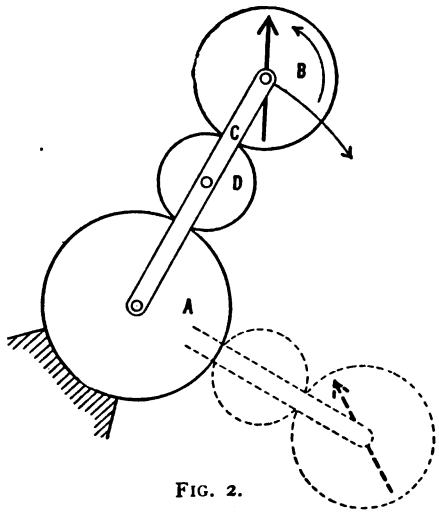

FIG. 2.

To make this clearer, suppose the wheels A and B to have 80 and 60 teeth respectively; then, if C were fixed, for every revolution of the wheel A in a negative direction the wheel B would make $1\frac{1}{3}$ revolutions in a positive direction. Now, if while the wheel A is making a single revolution in a negative direction, the whole of the mechanism be rotated one revolution in a positive direction, the wheel A will be stationary, and the wheel B will make $1\frac{1}{3} + 1 = 2\frac{1}{3}$ revolutions.

If an idle wheel D (Fig. 2) had been interposed, the direction of rotation of the wheel B would have been negative, and therefore, with other conditions the same as before, the wheel B would make $-1\frac{1}{3} + 1 = -\frac{1}{3}$ revolution. From this it will be seen that if the wheels A

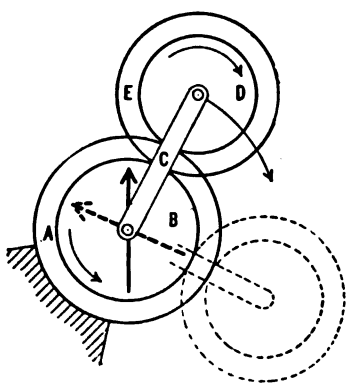

FIG. 3.

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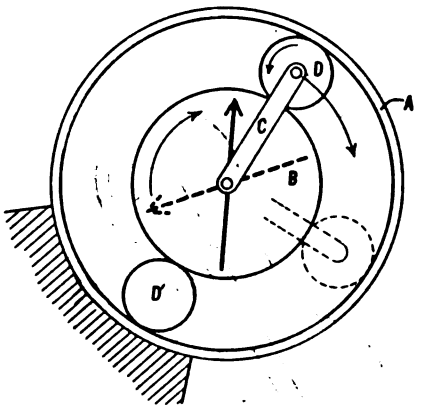

FIG. 4.

and B were equal in diameter the wheel B would not rotate.

In Fig. 3 is shown what is known as a compound epicyclic reverted train, in which the wheel A is still fixed, and the wheel B is mounted loosely on the same shaft as the wheel A, from which it is driven by the wheels D, E, which are both keyed on one axle.

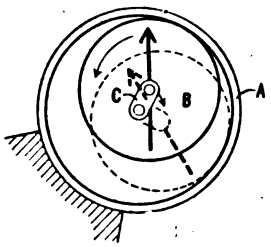

FIG. 5.

Suppose the wheels A and B to have 80 and 60 teeth respectively, as before, whilst the wheels D and E have respectively 50 and 70 teeth, the revolutions of the wheel B for one positive revolution of the link C would be

$$-\left(\tfrac{80}{50}\times\tfrac{70}{60}\right)+1=-\tfrac{28}{15}+1$$
$$=-\tfrac{13}{15}\text{ revolution.}$$

It will be evident that, by making the difference in the diameters of the wheels small, such a train will give the wheel B a very small rotary motion indeed for each revolution of the link C.

Fig. 4 shows an example of an epicyclic reverted train in which the wheel A is annular. In this form an extra wheel D' is usually placed opposite the intermediate wheel D, to act as a support. This case is similar to that shown in Fig. 2, except that the revolutions of the wheel B are positive. Suppose that the wheel A has 56 teeth and the wheel B 32 teeth; the wheel D will consequently have 12 teeth, since it is to gear with both the wheels A and B. The revolutions of the wheel B for one revolution of the link C will be

$$1+\tfrac{56}{32}=2\tfrac{3}{4}.$$

The arrangement shown in Fig. 5 is the same as that shown in Fig. 1, except that the wheel A is of the annular type, and the revolutions of the wheel B relative to the link C are negative. With the same number of teeth as in the example worked out with reference to Fig. 1, the revolutions of the wheel B would be

$$-\tfrac{80}{60}+1=-\tfrac{1}{3}.$$

In practice, however, it is usual to prevent the wheel B from rotating on its axis, and to allow the wheel A to rotate. If this were so in the above example, the wheel A would make

$$+\left(\tfrac{1}{3}\times\tfrac{60}{80}\right)=\tfrac{1}{4}\text{ revolution}$$

during one revolution of the arm C.

The applications of epicyclic gearing in modern machinery are extremely numerous and varied, many of them exhibiting great ingenuity. The advent of the motor car and the development of bicycles and tricycles have done more to increase the sphere of

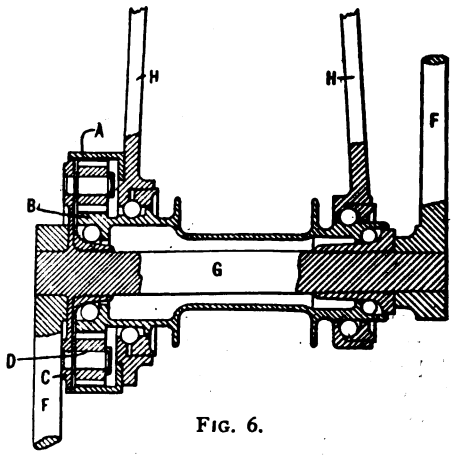

FIG. 6.

application of such gearing than any other branch of engineering.

One of the most well-known cases of an epicyclic train at the present day is probably the driving gear of the "Bantam" bicycle. This arrangement is also often called the "Crypto" gear. In Fig. 6 is shown a section through the hub of the front wheel of a "Bantam" bicycle. To the frame H is fixed an annular wheel A, concentric with the axle G, to which the pedals F are secured. A wheel B is formed in one with the hub of the bicycle

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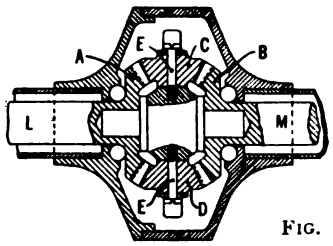

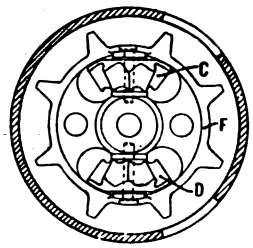

FIG. 7.

wheel, and is driven by means of the planet wheels D mounted on the disc C which rotates with the cranks F. To better comprehend the arrangement of the wheels, it will be well to refer back to Fig. 4, which is a diagrammatic end view of the gearing. Taking Figs. 4 and 6 together, it will be seen that the hub B rotates in the same direction as, but at a greater angular velocity than, the cranks F. Thus it is obvious that this arrangement gives a higher gear than by driving direct without the intervention of the toothed wheels. With driving gear of the proportions of the example worked out in connection with Fig. 4, an ordinary 24-inch wheel would be geared up to 66.

In Fig. 7 is shown a form of epicyclic gearing of wide application, known as Starley's balance or differential gear. The object of this arrangement is to enable the wheels of the driving axle of a motor car or tricycle to have a motion relative to each other when turning a corner. The axle is divided into two parts L M, provided with bevel-wheels A and B. These are driven by means of the chain wheel F, in which are mounted bevel wheels C D in gear with the wheels A B, the wheels C D being free to rotate on the spindles E. When the motor car or tricycle is running in a straight line, the two parts L M of the axle rotate at the same rate, and the wheels A, B, C, D remain in the same relative position to each other. When going round a curve, however, the two parts L, M of the axle will be rotating at different rates. This will cause the wheels A B to have a relative motion, thus turning the wheels C D on their axes. This rotation of the wheels C D does not in any way influence the driving effort of the chain wheel F. Practically all present day motor cars are fitted with differential gear of this or a similar type on their driving axles.

In some forms of bicycles, a bevel-gear similar to the above is fitted in the bottom bracket, and the two wheels C D are driven from the pedal cranks direct. The wheel A is fixed to the frame, and the wheel B is free to rotate on the crank axle. Mounted on the wheel B is the large chain wheel for driving the back wheel. This form of the gear gives the wheel B two complete revolutions for each revolution of the pedals, thus obviating the necessity for any very great difference in the diameters of the two chain wheels, and also affording an easy method of increasing the gear.

The practical application of the type of epicyclic train shown diagrammatically in Fig. 5 is represented in Fig. 8 as applied to the driving mechanism of a steam winch or capstan. In this, as in most applications of the same type, the annular wheel A rotates whilst the wheel B is prevented from rotating on its axis. The wheel B is mounted on an eccentric H, which is turned solid with the shaft F, and which has an eccentricity equal to half the difference in the diameters of the pitch circles of the wheels A and B. To prevent the wheel B from rotating, lugs G are formed on one side, which slide in vertical grooves in a circular disc D, which itself is fitted with similar lugs L free to slide horizontally in the groove E. Thus it will be seen that by rotating the shaft F the wheel B is carried round in a circular orbit without rotating on its axis, and thereby drives the annular wheel A with a relative velocity depending upon the difference in diameter of the two wheels. The wheel A is mounted loosely on the shaft F, and is connected to the winch or capstan by the clutch K. Gear of this type has also been applied to differential pulley-blocks and hand steering-gear for ships.

The necessity for rapidly changing the speed of motor cars without altering the revolutions per minute of the driving-motor has been the means of introducing several change-speed mechanisms, many of which have an epicyclic train as one of their

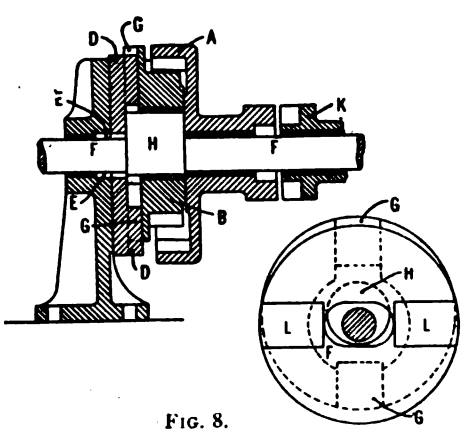

FIG. 8.

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constituent parts. The great advantage of such gearing for this purpose is that two speeds, at least, are always possible, since one speed is obtained by the gear running as an epicyclic gear, and another is obtained by locking the wheel train so that it turns as a whole.

The change-speed mechanism shown in Fig. 9, and known as Beaumont's change-speed gear, affords a good example of those gears which possess, as an important feature, one or more epicyclic trains. This gear may be mounted on an intermediate driving shaft, or on the main driving axle A of the car. It

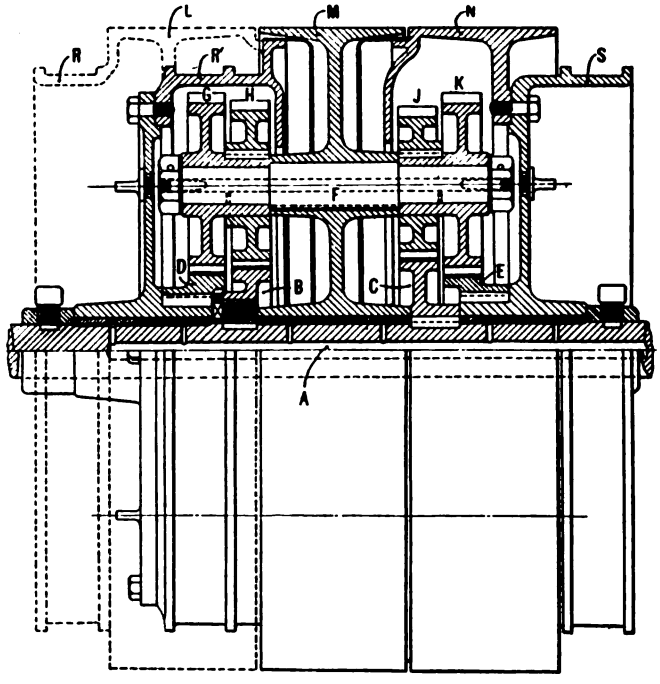

FIG. 9.

comprises three pulleys L, M, N, mounted loosely on the shaft A. Between these pulleys, and keyed to the shaft A, are toothed wheels B, C. Adjacent to these wheels are toothed wheels D, E, secured by keys to the bosses of the pulleys L, N respectively. Upon a spindle F, carried by the central pulley M, are mounted four toothed wheels G, H, J, K, in gear with the wheels D, B, C, E respectively. The wheels G, H rotate together, and form, with the wheels D, B a compound epicyclic reverted train, similar to that shown diagrammatically in Fig. 3. The four wheels J, K, C, E also comprise such a train, but one of different proportions to the wheels in the pulley L.

The pulleys L and N are provided with brake drums R, S, by which either can be held stationary, while the central pulley M is driven. If, for instance, the pulley L be held stationary by the band brake on the drum R, the gear wheel G will roll round on the wheel D and carry with it the wheel H in the same direction as the motion of the pulley M, thus driving the shaft A by means of the wheel B. It will be evident that the pulley N must be allowed to rotate loosely, otherwise the gear would become locked. On the other hand, if the pulley N is braked, and the pulley L is left free to rotate, the gear still being driven from the pulley M, the shaft A will be rotated by the wheel C at a different speed. By this means two speeds are produced. A third speed is obtained by running the belt on the pulleys L and M or M and N at the same time, which locks the whole of the gear and drives the shaft A at its highest speed. If means are provided for braking the pulley M, two more speeds may be obtained by driving either the pulley L or the pulley N. Therefore, by means of this mechanism, five different speeds of the shaft A are possible. If the pulley L is dispensed with, and a brake drum R' is fitted on the casing as shown, only four speeds are possible. Further, by choosing suitable proportions of the various toothed wheels in the gear, it is possible to cause one of the methods of driving to rotate the shaft A in a reverse direction.

The designs for change-speed mechanisms are exceedingly numerous, many of them being very ingenious combinations, comprising bevel-wheel epicyclic trains operated by special forms of friction clutches. It is in such mechanisms that epicyclic gearing finds the greatest number of applications at the present day.

The steering handles of motor cars are also fitted with a compound epicyclic reverted train in order that the steering may be what is known as "lock steering," or irreversible; that is, the tendency of the wheels to rotate the steering handle is prevented.

During recent years most of the large structural engineering and shipbuilding firms

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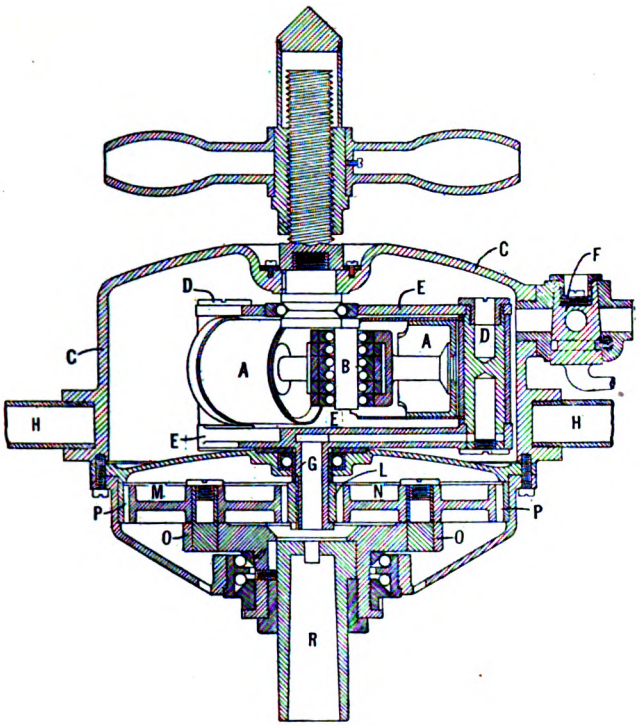

FIG. 10.

have fitted their yards with a complete installation of compressed air for working small tools. By this means the work on large structures, such as bridges and ships, has been considerably simplified and lessened. As a result of such a universal adoption of compressed air as a motive power, the various pneumatically-operated tools have been considerably improved. As a rule, the compressed air motors used for driving these tools run at a very high speed, too high for ordinary working. Some means must therefore be adopted to reduce this speed, and this has led to the application of epicyclic gearing in connection with such compressed air motors, one of the most notable being that shown in Fig. 10, which is a section of a Boyer pneumatic drill. The compressed air motor comprises three cylinders A set at equal angles in the frame E, and pivoted on spindles D which act as distributing valves, each cylinder working on the same crank-pin B. This crank-pin B is fixed to the outer casing C of the machine, and the three cylinders A therefore, revolve round it upon the admission of air under pressure by the valve F. The machine is rigged up against the work in a similar fashion to an ordinary ratchet brace, and is kept from rotating by the handles H.

At the lower portion of the hollow shaft G, which is in one with the frame E, is keyed a toothed pinion L. In gear with this pinion are two wheels M, N rotating on spindles fixed to the crosshead O, these wheels being in turn in gear with an annular wheel fixed in the outer casing. By this arrangement the pinion L, being rotated by the motor cylinders A, causes the wheels M, N to rotate the crosshead O at a reduced speed. The motion of the crosshead is transmitted directly to the chuck R in which the drill or other tool is held. In this form of driving mechanism the power being applied on opposite sides of the engine shaft, instead of on one side only as in the earlier forms of pneumatic drills, the forces on the gear are perfectly balanced.

Another example of epicyclic gearing in modern machinery is illustrated in Fig. 11, which shows a portion of Brown's hydraulic steering-gear. The steering-wheel A is mounted on a shaft F, and operates the rack G by means of the pinion H. At each end of the rack is fitted a piston working in an hydraulic cylinder, not shown in the figure. The movement of these pistons communicates by hydraulic

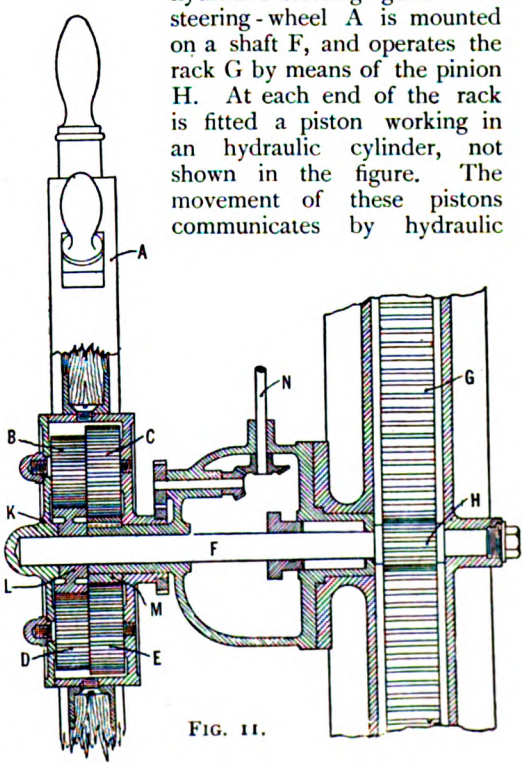

FIG. 11.

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pressure pipes the motion of the steering wheel to the tiller. Since by direct driving it would not be possible to obtain sufficient pressure on the piston to operate the tiller, recourse is had to epicyclic gearing to effect this object. The gearing is fitted in the hub K of the steering-wheel and comprises two pairs of wheels B, C, D, E in gear with a wheel L on the shaft F, and a wheel M attached to the frame of the apparatus. The rotation of the shaft F for one revolution of the steering-wheel A is arranged to be a very small amount, thereby producing the requisite pressure. A pointer, for the purpose of indicating the position of the rudder, is operated from the shaft N; its rotation is effected by ordinary toothed and bevel gearing from the hub K of the steering-wheel. In a recent form of Brown's steam steering gear, the steering engine is mounted on the tiller with the controlling valve co-axial with the rudder-post. This valve is operated by means of an epicyclic train similar to that shown diagrammatically in Fig. 4. The annular wheel is mounted on the rudder and to the valve spindle is keyed the central wheel, which is rotated by means of a planet wheel, the driving-arm of which is actuated from the steering wheel on the captain's bridge.

The above examples only serve to indicate the wide range of the applications of the epicyclic train. Several other uses might be mentioned which have either been introduced or greatly improved during the last few years. Such a list would include mechanism for operating and reversing the tables of printing machines, for regulating the tension of the yarn in spinning machinery, for lathes, for motor boat propelling apparatus, for hoisting machinery, for turning turrets in warships, for kinematographs and tube-expanders.

The great adaptability of this form of gearing will be obvious when the wide scope of the applications described and mentioned above is considered.

SELENIUM CELLS.

SELENIUM, an element belonging to the sulphur group, was discovered by Berzelius in 1817. This metalloid appears, like sulphur, in various modifications. When newly obtained by precipitation with acids out of a solution of selenic acid, it forms an amorphous, brick-red powder. By melting and then slowly cooling this, we obtain a black, shining and brittle mass, in appearance much like black sealing-wax. In this state selenium is almost a non-conductor to electricity. The conductivity is improved, however, by slowly heating this modification to 200° C., when the selenium assumes a crystalline condition, having a grey, metallic-looking surface. This property was first observed by Hittorf in 1851. In 1873, Willoughby Smith, an American electrician, announced the discovery (made by his assistant, M. E. Mayhew) that the element selenium in its metallic state possesses the wonderful property that its electric resistance decreases under the influence of light. He expressed his surprise thus:—"It is certainly puzzling to hear a fly walk across a microphone like a horse over a wooden bridge; but I should consider it as more wonderful still to hear a flash of light fall upon a piece of metal!"

W. Smith's statements were subsequently confirmed by the experiments of many others, and Adams found that the greenish-yellow rays of light are the most active. He also showed that the change of resistance varies directly as the square root of the illumination, and that the electric resistance is less with a high electro-motive force than with a low one.

Among the first who tried to put this remarkable property of selenium into practical use was Werner Siemens. In 1875 he devised a "selenium cell," consisting of two platinum wires, wound in form of flat spirals, the selenium being formed into narrow strips between these. In constructing a photometer, Siemens successfully obtained selenium cells with a sensitiveness up to 15 : 1; that is to say, the electric resistance of his selenium cell decreased in the ratio 15 : 1 when taken from the dark and placed in sunlight.

In 1879, Graham Bell and Sumner Tainter were carrying out quite different and highly interesting experiments with an apparatus

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which they called the "Photophone." They obtained selenium cells by placing small round discs of metal one on top of another, inserting thin and smaller discs of mica between these, and filling the remaining space between the metal discs with selenium. In this case the resistance of a cell, which in the dark was 300 ohms, decreased in sunlight to about 100—150 ohms. This comparatively small sensibility was compensated by the low resistance of the cells.

Many designs and constructions of selenium cells have been introduced since, and used in various experiments. As early as 1880, Perry, Shelford-Bidwell, and others, invented apparatus for transmitting photographs by the aid of selenium cells; whilst in 1890, Bidwell demonstrated, to the London Physical Society, the sensitiveness of selenium to light, using an apparatus containing selenium cell, sensitive relay, and electric bell.

Up to the present, only two types of selenium cell have survived. The flat selenium cell, invented by Shelford-Bidwell in 1880, consists of a thin porcelain plate, about $1\frac{1}{2} \times 2$ inches. On this plate are wound two thin wires, which are kept a certain distance apart by small slots cut in the edges of the plate. The selenium is spread on one side only. Kipp & Zonen, of Giltay Opvolger in Delft (Holland), have manufactured this cell since 1881.

The second type, a selenium cell of cylindrical shape with solid porcelain core, is at present being manufactured by the Berlin electrician E. Ruhmer, who recently succeeded, by the aid of his cylindrical cells and an up-to-date system of wireless telephony by light, in speaking over a distance of more than nine nautical miles.

The above two types of selenium cell are, as stated, manufactured with solid porcelain cores, and have thus the disadvantage of being exposed to the light on one surface only. The resulting loss of efficiency can only be overcome by using selenium cells without any core. The manufacture of such cells is, however, allied with considerable difficulties, and it was only after an enormous number of experiments that Mr. C. F. Adolph, of 14, Farringdon Road, E.C., succeeded in devising three types of selenium cell which are exposed to the light on both surfaces.

The sensibility of a selenium cell is thus increased fully 75 per cent., and the change of resistance takes place to the full extent almost instantaneously. The cells are manufactured in flat, cylindrical and conical forms, and do not differ much in sensitiveness: each can be employed for ordinary experiments; where the highest efficiency is required, however, it is advisable to choose the most suitable form. The flat selenium cell, having large plain surfaces, works most satisfactorily in diffused light, whilst the cylindrical and conical cells show certain advantages when fixed in focus of a concentrating lens, or a parabolic mirror.

The resistance of the selenium cells manufactured by C. F. Adolph and Company ranges from 2,000 to 60,000 ohms. They vary in sensitiveness from 4 : 1 to 15 : 1; that is, the resistance of a good selenium cell decreases in the ratio 15 : 1 when taken from the dark and exposed to bright sunlight. The E.M.F. to be used with these cells varies for different experiments from 2 to 60 volts: the current should not exceed 0·03 amperes. This comparatively low amperage is quite sufficient to actuate a sensitive galvanometer or a telephone receiver, therefore both can be

FIG. 1.—SELENIUM CELL.

enclosed direct in the circuit of the selenium cell and battery. Apparatus requiring a stronger current, however, must be worked with the assistance of a sensitive relay.

The selenium cells with plain surfaces (Fig. 1) are being manufactured after Siemens' method. Two thin wires are formed into flat spirals, and carefully placed on a small disc of mica. A thin sheet of crystalline selenium is placed on top, and the whole is put under slight pressure. This arrangement is heated to about 220° C., when the melting selenium slowly fills the narrow spaces between the two wires. After cooling, the cell is placed in a paraffin bath and slowly heated to about 180-200° C., when the selenium again assumes its crystalline condition. To show its sensitiveness to light, the cell can either be enclosed in the circuit of a battery and sensitive galvanometer, or can be put in the circuit of a Wheatstone bridge. The resistance of these cells varies between 2,000 and 10,000 ohms, and will

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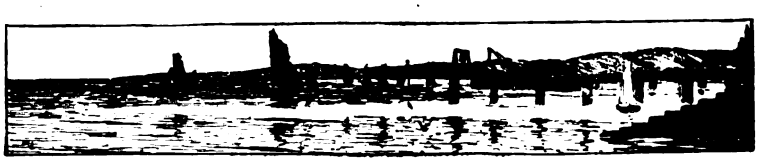
drop in the ratio 6:1 or 8:1 when the cell is exposed to bright sunlight. The diameter of these cells ranges from one inch to two and a half inches.

The " Photo-microphone " is an apparatus used for transmitting speech by the aid of light. This apparatus, as illustrated in Fig. 2, consists of a highly sensitive selenium cell, a manometric capsule with acetylene burner, a large concave mirror on an iron stand, and an acetylene generator. The selenium cell is connected with a battery of nine dry-cells and two telephone receivers by a long double cored cord; it faces the small acetylene flame, which is fed by the generator. The acetylene gas flows through the manometric capsule, which is provided with a large membrane of mica and a speaking tube. Speaking against the membrane will result in corresponding vibrations of the small acetylene flame, which will therefore continually alter its intensity: these vibrations of the flame can be observed in a rotating mirror. The selenium cell being thus illuminated, its electric resistance continually alters, and the oscillations of the electric current actuate the telephone membranes in true accordance to the operator's voice. Speaking, singing and whistling can be distinctly heard again in the telephone receivers, which should be taken into a distant room.

FIG. 2.—PHOTO-MICROPHONE.

The vibrating acetylene flame is at the focus of a concave mirror, in order to increase the illumination of the selenium cell. The insertion of a small disc of metal, cardboard, etc., between selenium cell and flame, will immediately stop the transmission. The apparatus will work in diffused daylight as well as in the dark.



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RECENT DEVELOPMENTS OF GAS LIGHTING.

By THOMAS HOLGATE, M.I.C.E.

THE exhibition of gas appliances at Earl's Court furnishes a convenient opportunity for directing attention to the great strides that, in recent years, have been taken in the economy and intensity of incandescent gas lights. Whilst the system of Auer von Welsbach, under normal pressures of gas and air, has developed both in the burner and in the mantle, yet the most striking instances of progress are in those that employ the gas or air at a pressure distinctly above that of the atmosphere. The advantage of using air under a pressure of 33 inches water column has been exemplified for some time past in the Scott-Snell lamp, and the use of gas at a pressure of 10 to 15 inches has received application by several firms, but the recent advances are in the direction of still higher pressures. The pressure of the gas in the consumer's service pipe is usually about 2 inches, whilst the new systems, by their special mechanism, raise that pressure to a working maximum of 55 inches, equal to 2 pounds per square inch. The methods of compressing are various, and are represented in the types now to be described in greater detail.

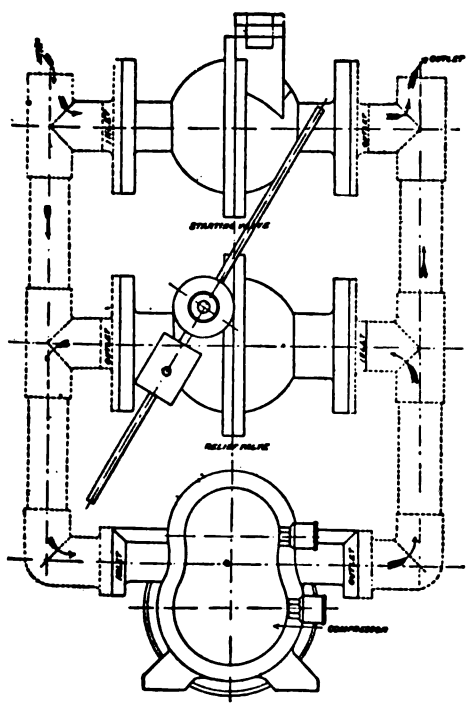

FIG. 1.—SALE-ONSLOW SYSTEM OF HIGH-PRESSURE GAS LIGHTING.

The one shown by Messrs. Thomas Glover & Co., Limited, is the Sale-Onslow system, which, originating at the Royal Gun Factories, Woolwich, where it has received extended application, has been adopted at the Government works at Enfield, and at Small Heath, Birmingham. The source of power at the Exhibition is a "Stockport" gas engine, driving a "Piftin" positive blower, and raising the pressure of the gas to 42 inches (Fig. 1).

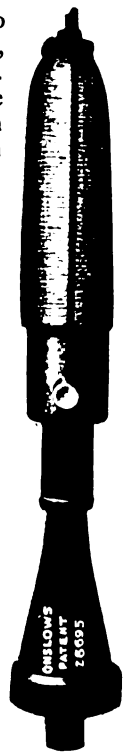

FIG. 2. ONSLOW BURNER.

The gas thus compressed is consumed in Onslow's burner (Fig. 2), by which a large and regulated quantity of air can be admitted. Single burners can be used up to 1000-candle power. The "Piftin" blower may be driven by any convenient motor, and when used in workshops is usually operated by a belt from the line shaft. In this case the compression of the gas ceases when the machinery stops at meal times or at the close of the day's work, and then automatically the gas is supplied at low pressure. In practice this is found to give as much light as is then required, and the variation in the number of burners in use or the pressure at which it is desired to work is similarly and automatically compensated for by a valve which allows the excess of gas to be returned to the inlet side of the blower.

For the result, in comparison with other methods of lighting, the makers claim that with 35 cubic feet of gas they can give 1000 candle power for one hour, which with ordinary incandescent burners, would require 66 cubic feet, and with flat-flame burners 333 cubic feet.

The Millennium Light, which has for a time been used in Germany, is now being supplied in this country by the British Compressed Gas Company. The apparatus consists of a

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reciprocating pump driven by any approved motor, such as a gas engine, electro-motor, or running shaft, and the gas thus enforced is received in a gas-holder, which in turn operates a control upon the motor. The gas-holder is weighted to the desired pressure, and any gas delivered into the holder beyond that required for use in the burners at work, causes it to rise and actuate mechanism which stops the motor, or throws the belt on to a loose pulley. The burners are plain tubes and the mantle rods are external, whilst the mantles are double fabrics and are supplied without stiffening compound.

The mantles may in this form be handled and carried about without fear of damage, and by "burning off" and thereby shrinking before application to the lamp, the efficiency is increased 13½ per cent. over those treated with collodion. It is claimed that under working conditions of constant pressure the maximum light is maintained for 500 hours burning, after which it pays to renew the mantle. The light units may be of 30 to 2000-candles power, and it is for the larger units that the system provides maximum advantage. Owing to the high state of incandescence and the large quantity of heat, the glass for the lanterns must be of a specially prepared kind. That used is from the Siemens factory at Dresden; it is incapable of being cut by a diamond, and is very tough and durable. Table I. is condensed from the "Journal für Gasbeleuchtung," and the costs are calculated from the illuminating powers on the basis of 2*s.* 8*d.* per thousand cubic feet of gas, and electricity at 4·096*d.* per Board of Trade unit, the average ruling prices in London and suburbs.

TABLE I.

Kind of light	Candle power	Consumption per hour		Cost per 1,000 candles per hour		
		for light stated.	for 1,000 candles.	pence.	relative.	
		cubic feet	cubic feet			
Millennium (Gas)	1,232	42·40	34·4	1·103	100	In these figures nothing is included either for mantles in the case of gas, or carbons and glow lamps in the case of electricity.
Ordinary Incandescent	63	4·24 units	67·3 units	2·158	195	
Bremer (Electric)	1,000	0·5	0·5	2·048	185	
Arc (Electric)	500	0·375	0·75	3·072	278	
Nernst (Electric)	180	0·218	1·21	4·956	449	
Incandescent (Electric)	16	0·055	3·44	14·090	1,277	

The following comparison (Table II.) of the tenders recently submitted to the Westminster City Council relate to the lighting of Aldwych, now served by the Millennium system.

The Pharos Light has just been introduced into England from Hamburg by Mr. B. A. List, as agent for the United Kingdom and the United States of America. The larger units are intended to take the place of electric arcs, whilst in their greater diffusive power and economy it is claimed there is considerable advantage. The features that distinguish the system from its predecessors are to be found in the mode of increasing the pressure and in its regulation, and also in the measurement of the gas under compression. The compresser itself is rotary (Fig. 3), and is usually mounted close to an electric motor; both stand on a rectangular vessel that is internally divided into two sections, which act as suction and delivery chambers. The regulation is accomplished

TABLE II.

	Cost of installation per lamp.	Maintenance and supply of light yearly.
	£	£ *s.* *d.*
The Gaslight and Coke Company (Millennium incandescent gas)	20	15 10 5
Wm. Sugg & Co., Ltd., intensified incandescent gas.	32	24 12 6
Scott-Snell Self-Intensifying Gas Lamp Company	33	25 0 0
Charing Cross Electricity Supply Corporation	45	27 0 0
Metropolitan Electric Supply Company	45	27 0 0

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by the return to the inlet of any gas in excess of that required for immediate use, and the pressure is usually 100 mm. of mercury, equal to 53·464 inches of water. The makers claim great compactness in the apparatus and the absence of any gas-bag or gas-holder with its water-seal, and the maintenance of a uniform pressure. The degree of compression is adjusted through a piston regulated by means of a draw-spring, which returns the surplus gas from the pressure conduit to the suction conduit. A connection pipe from the suction-chamber to the pressure-pipe provides for the feeding of

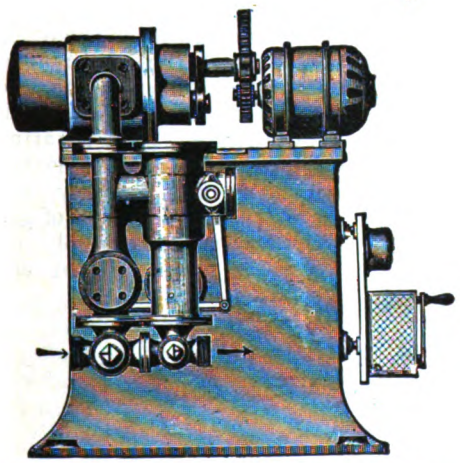

FIG. 3.—PHAROS COMPRESSER AND CONTROLLER, ELECTRICALLY OPERATED.

the "lighter" flames. The bye-pass, thus provided to the small flames underneath the principal ones, is controlled by a diaphragm which, at high pressure, stops the admission of gas, but reopens at normal pressure when the supply to the mantle is shut off. The diaphragm "lighter" is supplemented with dust-removers from gas and air supplies, whilst the burners have adjustable mantle-holders with horizontal magnesia rods.

A series of tests carried out by Prof. W. Wedding, of the Royal Technical School, Charlottenburg, were made to ascertain the efficiency of the compresser in the conversion of energy and of its constancy in pressure under varying demands for gas. The results of these tests are given in Table III.

The initial pressure from the town main was 2·85 inches water-column, in which term

TABLE III.

Pressure increase by compressor.	Gas compressed per hour in cubic feet.	Maximum variation of pressure.	Pressure on suction flange.	Consumption of current in Board of Trade units.	Work done in compression joules per hour.
50·279	321·375	0·39	1·417	·202	188,700
53·075	250·743	0·31	1·535	·212	155,200
55·437	190·706	0·31	1·574	·214	122,300
55·988	129·96	0·27	1·732	·219	83,800
56·775	64·628	0·19	1·771	·219	42,200
57·800	none	0·19	1·771	·219	—

the pressures given in the tables are stated. The consumption of current represents about 1*d*. per hour, whether the machine is running idle or at full capacity, and this is not largely exceeded at overload, as shown by Table IV. The latter tests were made with the bye-pass closed, when, of course, higher pressures and greater volumes of gas were dealt with. Professor Wedding states that, where gas from the compressed service was suddenly withdrawn, reducing the amount from 271 to 137 cubic feet, burners in the close vicinity of the apparatus were not visibly affected.

TABLE IV. (W. Wedding).

Pressure on outlet of compresser.	Pressure on inlet of compresser	Consumption of Gas per hour at 1·85 ins.	Consumption of current in B.T. units.	Work done by compresser in joules per hour.
53·14	1·10	441·45	·208	257,000
62·59	1·12	409·56	·220	282,000
72·83	1·16	388·47	·231	306,000
82·28	1·40	328·43	·252	330,000
105·51	1·40	310·78	·271	346,000

TABLE V.

Cubic feet of gas used per hour.	Measured candle-power British candles.	Candles per cubic foot of gas per hour.	Particulars of test and authority for the larger original return.
10·77	306	28·4	The gas was compressed to 1400 mm. = 55·12 ins. The tests were made in the Government Physical Laboratory, Hamburg, under Dr. C. Jensen and W. Volge, engineer.
15·26	450	29·5	
19·00	591	31·1	
25·25	958	37·9	
30·55	1297	42·4	

The fact that on the inlet to the compresser there was always a pressure above

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FIG. 4.—PHAROS WORKSHOP LAMP.

atmospheric, shows the possibility of supplying ordinary gas lights, whether flat flame or incandescent, without oscillation and from the same gas meter. The lamps in which the high pressure is utilised are designed to shield the eye from the direct light by providing large diffusing surfaces.

The apparatus of the Air Light Company, Limited, is novel in several of its features, and is, in the "Century" light, arranged for increasing the pressure of the air supply, as distinguished from most other systems where the gas is compressed (Fig. 5). The object of gas compression is to induce an increased flow of air to the burner; the same result is attained by the "Century," through direct action upon the air supply. To accomplish this purpose a small increment of pressure above that of the atmosphere is all that is employed, where conduits of sufficient sectional area are permissible. These conduits may be of wood, or of thin sheet metal, as in any case leakage is not of any moment, and the only essential required is that they should give only a small resistance. Where this is complied with, the pressure used is only one-tenth to one-fiftieth of an inch of water-column, and this impetus may be most conveniently given by a fan driven by an electric motor, or water-jet working a Pelton wheel. The air is delivered in an annulus around the gas nozzle, thereby inducing the flow of the gas, and mingling intimately therewith before reaching the burner-head; according to the Company's patent No. 13670, of 1904, the supplementary air around the mantle may be furnished from the air-conduit. The fan is without any regulating device, because the air-supplies to the burners are never shut off, and therefore the quantity of air flowing is constant, the fan being stopped when the last light is shut off.

Another method of achieving the same end, *viz.*, the production of 40 candles per cubic foot of gas consumed, is provided by the same Company under the name of "The Permetor" (Fig. 6). Like the Selas system (see TECHNICS, Vol. I., page 544), a mixture of gas and air is placed under pressure and delivered to the incandescent burner. This previous admixture of two volumes of air to one of gas is accomplished by a rotating cylinder, which receives in one orifice, on its periphery, one volume of air, next one of gas, and thirdly another of air. These are then mingled and compressed into a storage-holder, weighted to give the desired pressure of three inches, and fitted with a device by which, when sufficient of the mixture is stored, the electric current is switched off from the motor of the mixer and compresser; when the stock of gas

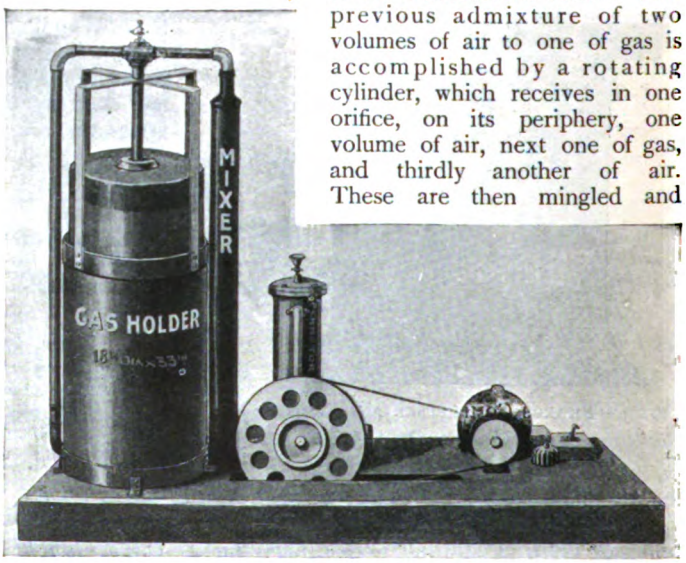

FIG. 6.—COMPRESSER, CONTROLLER, AND GASHOLDER OF THE "PERMETOR" SYSTEM.

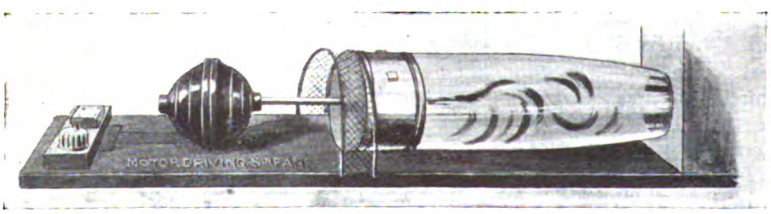

FIG. 5.—"CENTURY" AIR PROPELLER.

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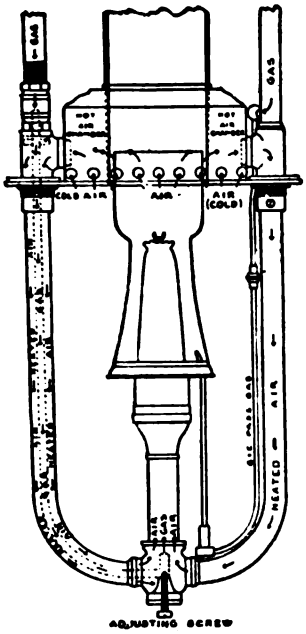

FIG. 7.—THE "PODMORE" RECUPERATIVE LAMP.

falls, the switch is put on again. In consequence of the delivery, at an enhanced pressure, of both gas and air to the burner-nozzle, the ingathering of the remaining proportion of air necessary to secure complete combustion is facilitated.

The next class of incandescent lights to claim attention is that in which no mechanical appliances are employed, but where the air and gas are pre-heated by the products of combustion. This type, as made by A. E. Podmore & Co., is shown in Fig. 7, which is almost self-explanatory. The cold air, admitted to a chamber above the mantle and special glass chimney, is heated *en route* to the two descension tubes, and thence to the burner mixing tube, where it meets the gas, likewise heated in a small tube placed within one of the air descension tubes. As the volume of air required for primary combustion is about six times that of the gas, it is manifestly of greater economy to heat the former than the latter. The glass chimney already referred to is shaped so as to direct the supplementary air on to the apex of the mantle, where, normally, the temperature is lowest. The quantity of gas may be adjusted by a screw, as shown, and the suction of both air and gas into the mantle is aided by a metal chimney surmounting that of glass. The whole arrangement permits of convenient suspension of the lamp, and the carrying of the reflector so as to throw the light downwards at useful angles.

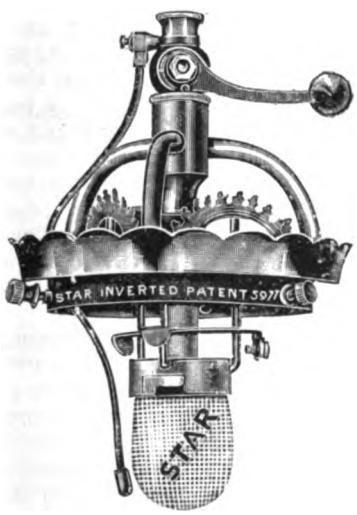

FIG. 8.—"STAR" INVERTED BURNER WITH BYE-PASS.

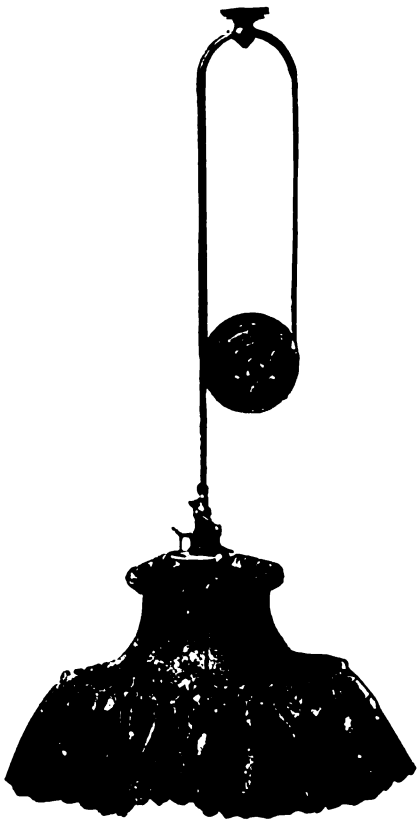

FIG. 9.—THE "HANWELL" FLEXIBLE TUBE PENDANT, ADAPTED TO INVERTED BURNER.

The great advantage of a concentration of light downwards, just mentioned, is recognised in the inverted type of burner, of which we illustrate that made by the Star Inverted Incandescent Burner Company. The fact that air and gas must be delivered against gravity to the interior of the mantle requires that extra

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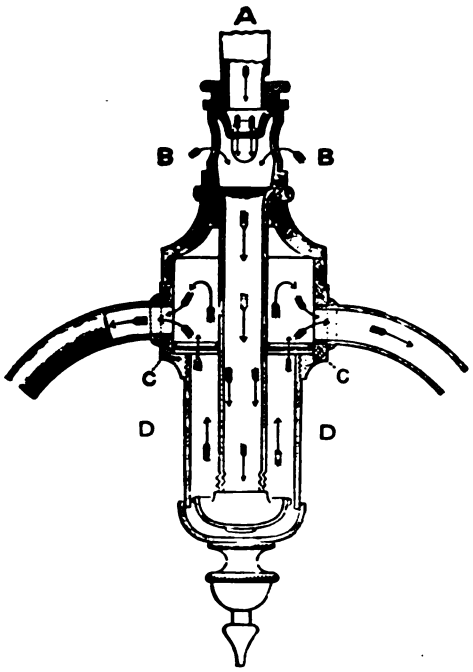

FIG. 10.—"DARWIN" SYSTEM.
B, B, air inlets. A, gas supply. D, mixing chamber.

precautions shall be taken to prevent "striking back." If the products of combustion be allowed to enter the air channels, the carbonic acid and water vapour which they contain will check combustion, instead of aiding it as pure air will do. These fundamental considerations have been embodied by "the air supply being taken cold from the outer circumference of the coronet of the burner through three air tubes, whilst the air and gas admitted through the tubes to the mixing chamber are conveyed to the point of combustion in such a way that the explosive mixture is not reached" (Fig. 8). The mantle is held by a ring made as a bayonet joint, and the products of combustion must pass through the fabric of the mantle, and so raise its temperature to incandescence before passing away into the atmosphere.

The combination with the lamp of a bye-pass light and of the "Hanwell" rising and falling pendant makes the convenience of its use very considerable, whilst the small units and the graceful designs that are made possible, add decorative effects akin to those of the electric glow lamps (Fig. 9). The original application of the Hanwell pendant just referred to has been developed, so that it may be used with upright burners. For these an elliptical harp is fitted with a detachable clip, with a brass stamping that carries an ordinary or silk lampshade. The stamping is adjustable, so that the shade-holder may be raised or lowered to suit various lengths of burners. The use of flexible metallic tubing in the pendant enables a simple gas-tight conduit to be maintained, whilst varying the distance from 3 ft. 7 in. to 7 ft. 3 in. from the ceiling. When used with an inverted burner the thumb piece of the cock is fitted with vulcanite, and the movement of the shade and lamp as a whole may be made by a touch of the fingers without excessive heat, even after several hours of use. The parallelism with electric glow lamps already mentioned is extended by this simple device.

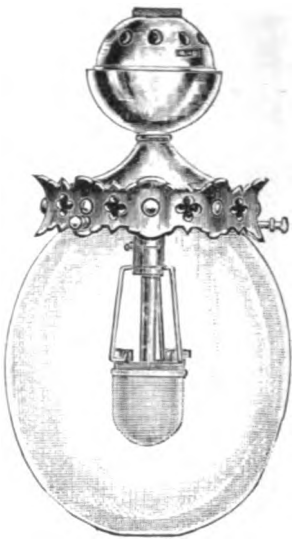

FIG. 11.—THE "GLOBE" INCLINED BURNER.

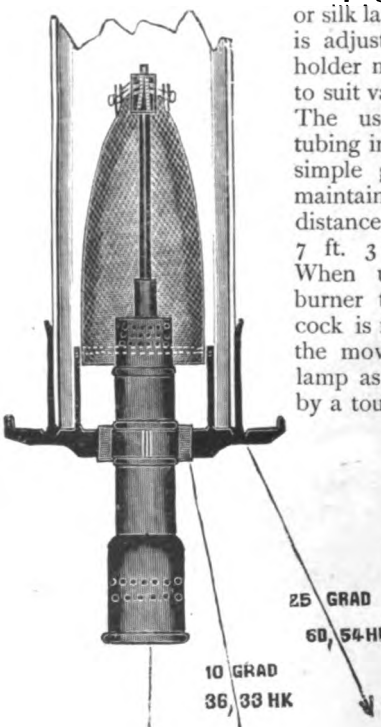

FIG. 12.—"WITT" UNDERLIGHT BURNER.

The "Darwin" light of the Wright and Butler Manufacturing Company, whilst being made for single burners, has distinct advantages for application to groups of burners. It is provided with a mixing chamber of large capacity to

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serve a number of inverted burners of predetermined magnitude. The mixing of the gas and air is facilitated by wire-gauze, which prevents striking back, as shown in section, Fig. 10.

The Globe light shown in Fig. 11 possesses a special feature in its working, either as a vertical, inverted, or inclined burner. The mixing of gas and air is effected in the ball-like chamber, where the gas enters at the top and the air at the side orifices. The prolongation of the tripod outside the tube, within the glass globe, for the purpose of holding the collar of the mantle, is also shown.

The burner and its mantle will withstand considerable vibration, and the brass adapters supplied enable the light to be applied to existing gas brackets or pendants.

The "Witt" patent underlight burner is shown in Fig. 12, and is intended to secure a more uniform spherical illuminating power than usual. For this purpose the space between the burner head and the mantle is left unobstructed by any metal work, and to provide a support to the mantle an outer ring encloses it. The burner head is of smaller diameter than usual, being large enough to hold the mantle fork, but the gas is dispersed around the circumference of the tube, and not out at the top. As a contrast, the "Kern" burner in many of its forms is fitted with a perforated husk, which, added to the large diameter of the burner head, interposes a large obstruction to light, which it is the aim of the Witt system to avoid. Table VI. gives the results of photometric measurements by Dr. Carl Meyer and Dr. C. Enoch, who sign as Chemists of the Berlin Board of Commerce, relative to the distribution of light at various angles which are shown in Fig. 12.

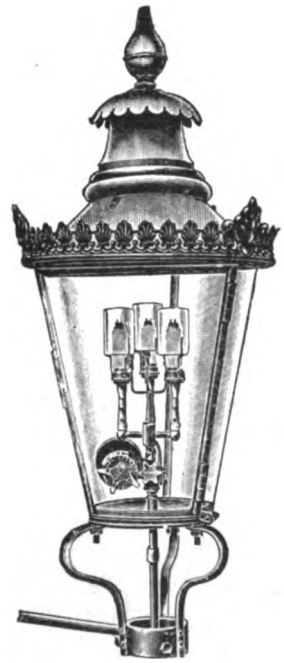

FIG. 13.—GUNNING'S CLOCKWORK LIGHTER.

The quantity of gas used in each test is not stated, but there is no doubt from actual inspection that the light in a vertical direction and at small angles with the vertical is much improved by the Witt arrangement.

The various systems of lighting thus far mentioned are equally applicable for indoor and outdoor lighting, but those that follow find their chief place in public street lamps.

The Gunning automatic lighter (Fig. 13), exhibited by the Automatic Light Controlling Company, is actuated by clockwork, and is fitted with a spring capable, when wound up once per week, of igniting and extinguishing the light at predetermined hours each day. Not only so, but it may be used to turn off a portion of a group of lights at, say, midnight, allowing the others to remain alight until a later hour; or, again, it may be used to give light for several hours in the evening and several hours in the morning, with an unlighted interval. All these are operated by arms that may be fixed at various points upon the rim of a graduated wheel, gearing into a toothed wheel fixed upon the plug of the gas cock, the position of the arms being set each week to the required hours by the man when winding up the clock. Bye-pass flames are used to effect ignition.

The Rotary Meter Syndicate, Limited, are showing meters (Fig. 14) capable of measuring air and other gases with considerable accuracy, without incurring large capital expenditure. The value of this fact extends in two directions, enabling meters, on the one hand, to be applied to each separate gas-fire or other small apparatus, and on the other enabling

TABLE VI.

Angle tested.	Witt Burner.	Original Auer-Welsbach.	Auer system, 1 sieve.	Auer system, 2 sieves.	
Vertically	28·55	0·49	0·40	0·38	The illuminating powers are given in Hefner candles each = ·88 English candle.
Angle of 10 degrees .	36·33	6·04	4·46	3·90	
Angle of 25 degrees .	60·54	26·14	19·96	16·15	
Horizontally . . .	101·40	96·07	73·64	59·85	

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large volumes of gas or air to furnaces to be measured, which would otherwise entail prohibitive cost for the meter and its proper housing. Ordinary wet or dry meters are unsuitable for dusty gases or vapours, but the facility with which the "Rotary" may be installed in duplicate, and the ease with which the mechanism can be taken out and replaced by a clean one in a few hours, constitute a great recommendation. The working, as there are no leather diaphragms or water seals; and the moving parts being subjected in all parts to approximately the same pressures, are in equilibrium. On view is a rotary meter of about three inches diameter and similar height, passing gas as a check through a test meter *en route* to a gas fire, showing its applicability to determine the discount due to a consumer where there exists a differential rate for heating gas.

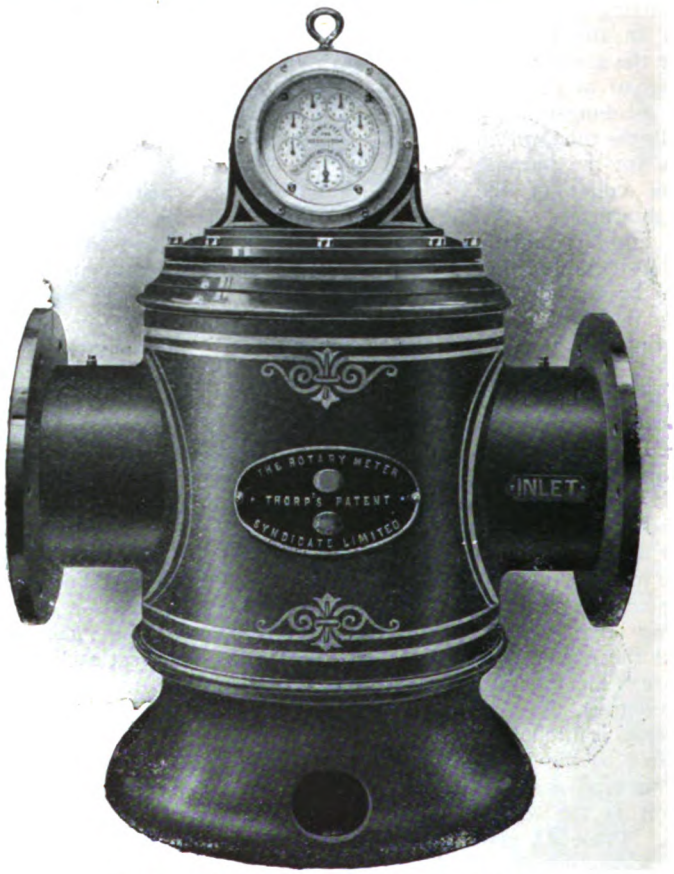

FIG. 14.—THORP'S PATENT ROTARY METER.

meter has been used in a variety of works for some time past, so that it may be regarded as having passed the experimental stage. Its small dimensions, small weight and low cost make it applicable where the meter complying with the Sales of Gas Act would not be eligible. The rotary meter depends upon the movement of a frictionless set of vanes, and the vertical shaft therefrom gears into an index and is read in the ordinary manner. The pressure at which the gas is passed through the meter does not affect its

A new device in connection with prepayment gas meters is the change-giving mechanism (Fig. 15) of Messrs. Rotherham & Sons. When a penny is used in the gas meter it falls into the change-giving attachment and records itself upon a dial placed there for the purpose. When the dial shows that six pennies are in the box (but not before) a sixpenny piece can be inserted in the slot under the lever provided, and the ring near it pulled forward. The six coppers will then be released and the sixpenny coin will fall

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into the locked-up box provided at the bottom. The ring must then be pushed back home, and the mechanism is ready to repeat the operation. After the dial records that six coppers are in the box a seventh and an eighth may be used for obtaining gas, but then it is necessary that six of them must be relieved by a sixpence before any more gas can be obtained. The collection of large quantities of copper coins has created a difficulty to both the consumer and the gas supplier, which the device mentioned, intelligently used, may be able to avoid. It is obvious that the principle is capable of extension to shillings or coins of other denomination.

S. Cutler & Sons have introduced to this country from Germany the "Ados" carbonic acid recorder. It may be used for testing the chimney gases from settings of retorts, boilers, and other plant where an excess or deficiency of air is suspected, and also for ascertaining the CO_2 content of producer gas, Mond gas, blue water gas, or carburetted water gas. The importance of such a continuous record can scarcely be over-estimated, and if the instrument fulfils expectations it will open the way to progress in many industrial operations. The one guiding factor in the matters above mentioned is carbonic acid, and recognising the importance of a record, several machines have previously been devised, most of them depending upon the varying specific gravity of the chimney gases. Such a method restricts the applicability of the principle, which appears to be more fully available in an absorption apparatus. It is upon this latter principle that the "Ados" works, and it consists in its mechanism essentially of four parts.

1. The motor, which is the large holder shown in Fig. 16. This acts by virtue of the chimney draught, which exerts its power through the flexible tube, and its rate of action is determined by the extent to which the cock upon it is open. The rising and falling of this holder affects the gear upon the disc above it, and therewith the two smaller holders alongside.

2. The last-named holders receive the sample of gas to be tested, rising and falling alternately, drawing the gases and then forcing them into the absorption vessels, which are supplied with a solution of caustic alkali (potash or soda).

3. The absorption vessels, having absorbed the CO_2 in the gas, cause a reduction in volume.

4. The recorder, by a pen moved by the extremity of a lever, marks upon a paper, fastened round a drum, the percentage volume that has been absorbed.

The number of tests per hour is under control, and may be varied to suit the times of a water-gas "run," or any other cycle of operations affecting the percentage of carbonic acid produced.

The loss of fuel when chimney gases contain a lower percentage than the theoretical maximum of 21 per cent. of CO_2 depends upon the percentage of hydrogen in the fuel used, and also upon the percentage of carbon monoxide present in the chimney gases; the latter, caused by insufficiency of air, being even more objectionable than excess of air.

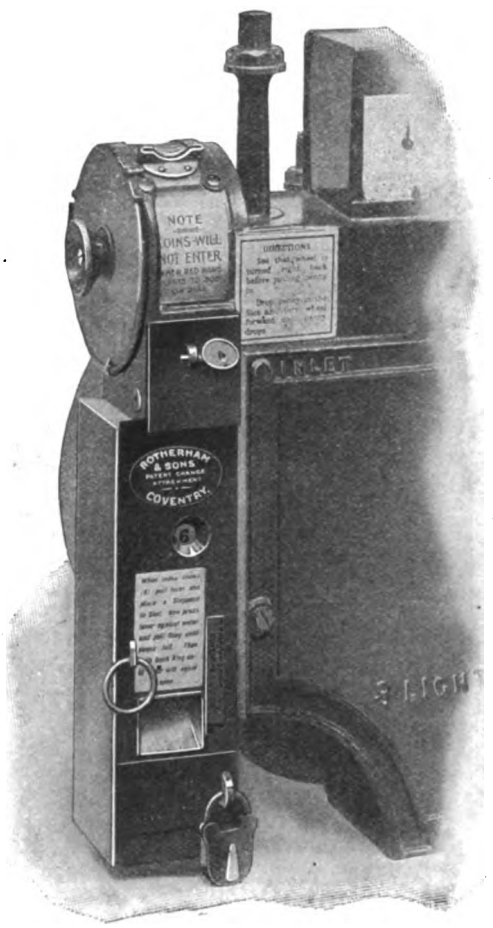

FIG. 15.—CHANGE-GIVING PREPAYMENT GAS METER.

The Rotary Meter Syndicate are exhibiting a carbonic acid indicator which depends

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upon the absorption of the CO_2 by caustic alkali, measuring the rate of flow to the absorber by a float gauge, and similarly the outflow by another float gauge. The difference in the two rates shows the percentage of CO_2 absorbed at the moment of observation. It is intended for use with water-gas plants.

(*To be continued.*)

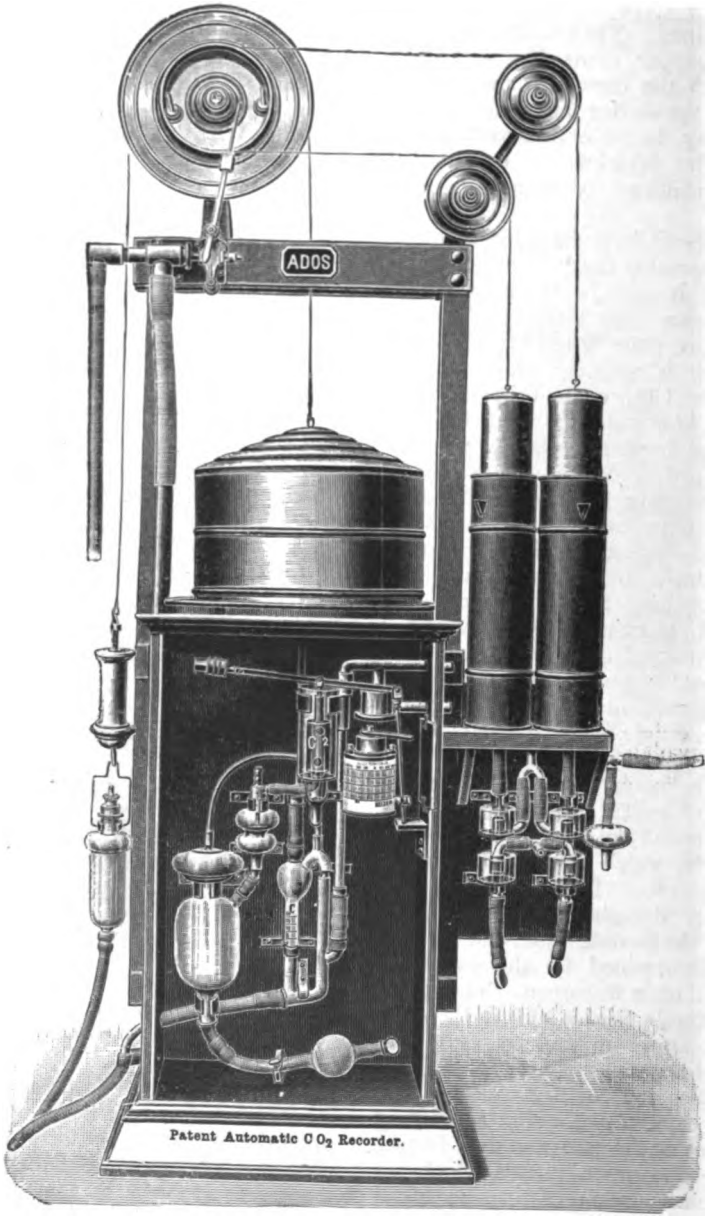

FIG. 16.—"ADOS" CARBONIC ACID CONTINUOUS RECORDER.

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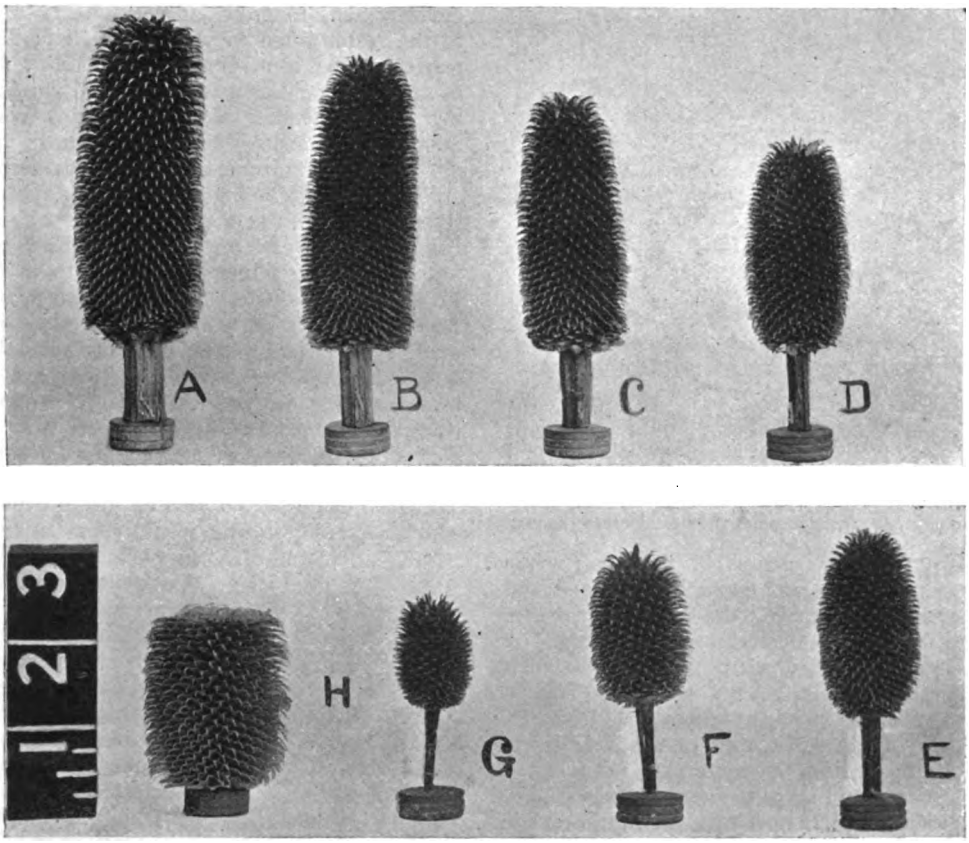
THE TEAZLE AND ITS COMPETITORS.

By H. HIELD.



TEAZLE HEADS USED IN THE TEXTILE INDUSTRIES.

The scale at the side is in inches.

A—King Teazle, for seals, rugs, reversibles, etc.
B—G Teazle, for blankets, beavers, pilots, etc.
C—O Teazle, for light blankets, rugs, medium cloths, broad cloths.
D—P Teazle, for unions and other fine-napped cloths.
E—P.T. Teazle, for mantle cloths and flannels.
F—T Teazle, for very thin mantle and dress goods and gloves.
G—Button Teazle, to be used with C, D or E.
H—Cut Teazle, for the rotary gig, for blankets, felts, flannels, etc.

FROM the time of Richard the First the teazle has been cultivated for industrial uses, and has been an indispensable tool to the dressers of woollen and worsted cloths. The following article is intended to give a comprehensive account of its structure, use, etc., together with details of its more recent competitors. The teazle plant belongs to the natural order *Dipsaceæ*, and when full grown reaches a height of four to six feet. The head, which grows a dense cluster of very small flowers, forms the only part of the plant which is of use.

Fig. 1 shows a drawing of the cultivated variety of teazle, *Dipsacus fullonum:* this is the variety alone used in commerce. It will be seen that the head forms a slightly tapering cylinder, being composed of a large number of curved awns springing from a thick woody core. Each of these awns is armed with a very fine hook at the extremity, and one and all grow with the hooks pointing downwards, all at about the same angle. It is in the interstices between the awns that the tiny flowers grow when in bloom, and here also are formed the curiously shaped seeds (see Fig. 2). After the flowers have bloomed and died away, the teazle hardens, and loses its

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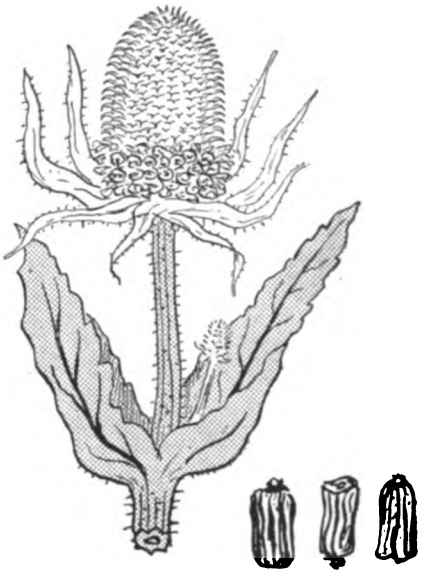

FIG. 1.—CULTIVATED TEAZLE (*Dipsacus fullonum*). FIG. 2. TEAZLE SEEDS.

fluids, from the action of the sun; when properly grown and cured it forms an ideal instrument for raising the wool on a fabric into what is technically known as a "nap." A specimen teazle, properly grown, forms such a perfect cylinder that it appears more like a piece of man's handiwork than that of Nature. Figs. A to H, at the head of this article, are reproduced from photographs of selected specimens, and show the general sizes in use. Besides the finely-developed hook, the shape of each individual awn seems specially constructed to combine elasticity with strength and lightness.

Fig. 4 shows the contour of the awn, and also the V-shaped groove running up the centre. This groove materially adds to its strength, and is itself a device often used in mechanical construction. One other notable feature about the growing plant is the large double leaves which form a cup around the stem; this forms a most efficient reservoir for moisture, playing an important part in collecting and storing it for the plant's use.

Fig. 3 shows the common wild teazle, *Dipsacus sylvestris*. The general structure is much on the same principle, but the awns of the wild variety are much longer and more slender, besides having only a very small and weak hook. The teazle requires two years to come to maturity, and after the first year is thinned out, which is known as "spittling." During the second year the plants commence to run—that is, to throw up the long flower-bearing stem; in the autumn they are ready for cutting and curing. Teazles require a good rich soil, and are supposed to take considerable nutriment out of it. The plants are very easy to grow, but very uncertain as to the result when they are harvested; thus teazle-growing is a very precarious following, as the crop is either made or marred, according to the weather after flowering. While good soil is essential for strong growth, fine dry weather is indispensable for good curing, and a wet week coming at the cutting time is sufficient to ruin the crop.

Some teazles are grown here in England, but our climate is not suitable for them, on account of its vagaries. France, Austria, and America now send considerable quantities over, France being specially noted for the large king teazles, while America has a reputation for the smaller kinds. Formerly teazles were sent to the consumer just as packed by the grower: now they are usually sorted and graded up according to their various qualities. To anyone unacquainted with the trade, sorting would seem a very simple business. Undoubtedly, separating them into sizes is easy, but the mere fact of size is apart altogether from strength of awn, density of head, elasticity, and other little points which require experience and a trained hand and eye. We now have to consider the uses they are put to, and the methods of using them.

FIG. 3.—WILD TEAZLE. (*Dipsacus sylvestris.*)

Formerly, when nothing but broadcloth was worn by the well-to-do classes, teazles were used on a much more extensive scale, as the teazle head was the only means of forming that soft, silky face which the fine cloths were noted for. Before the introduction of the teazle gig, all the raising was done by hand, the teazles being set in handles of the shape shown in Fig. 5. With one of these in each hand, the workman made long sweeping strokes across the surface of the tightly-stretched fabric, drawing the wool out of the cloth, and leaving it to form a soft velvet-like

FIG. 4.—AWN.

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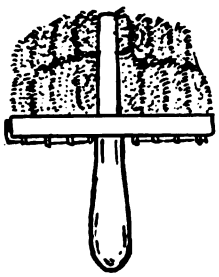

FIG. 5.—TEAZLE HEADS FITTED INTO HANDLE.

surface. The great art of raising was to get a thick, even cover, without marks or streaks of any description, and not to pull the wool off. The structure of the teazle is admirably adapted for this, as while the hooks are keen enough to grip the fibres, the awns are so elastic as to bend and release them rather than drag them away. This keenness and spring constitute the most valuable properties of the teazle, and for certain classes of material teazles are yet superior to any mechanism that has been invented.

Fig. 6 shows the old-fashioned frame used for cross raising; this was known as a "crow"; and the cloth was hooked on for about four

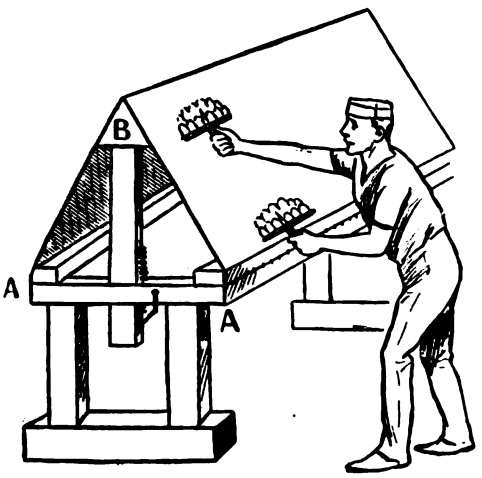

FIG. 6.—OLD-FASHIONED FRAME (THE "CROW") USED FOR CLOTH NAP RAISING.

yards at each selvedge. A, A are two long beams carrying teeth, and constructed with hinges to lift up when the cloth is to be released. After hooking the fabric on at both sides, the jaws were secured and the central beam, which was shaped like an inverted V, was raised by means of a rack and pinion. This strained the cloth tight, as shown in the figure, so that two men could work, one at each side. The straining beam is marked B in the diagram. All the work done on this frame was of course along the weft way of the cloth; this was necessary, so as to get a thick mossy cover on, very full in the bottom.

Following this came raising the cloth in the direction of the warp on the frame known as the "Nelly" (see Fig. 7). Here two wooden

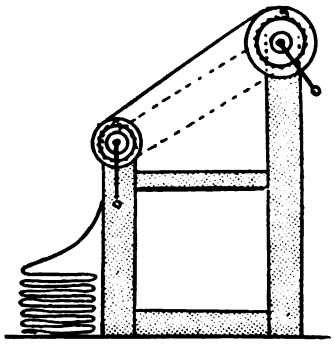

FIG. 7.—THE "NELLY."

rollers were fixed in a frame about a yard and a half distant from each other; the cloth was passed through a long slit in the lower roller and the end wrapped around the upper. Both rollers were then turned by handles in opposite directions until a suitable strain was got on the fabric, ratchets and pawls to each roller keeping the tension required. Then the workmen used the handles again, but this time in the direction of the warp. After this came the invention of the rotary gig, which is still used, with very little modification from the form used fifty years ago. With the gig the teazles were set in a long iron frame, a diagram of which is shown, together with the section, in Fig. 8. After setting, twenty-four of these frames were mounted on the circumference of a large iron cylinder, and the cloth to be raised had to travel over this while the cylinder was revolving in the opposite direction.

Fig. 9 shows the method of mounting these frames on the cylinder: Fig. 10 gives a diagram explaining the general working of the machine. A is the large cylinder carrying the rods. The cloth in the form of an endless band travels over the small rollers F, F, down and under the roller B. This last roller, which is known as the "breast" roller, works with a rack and pinion, so that it can be quickly raised or lowered; lowering it presses a larger area of the fabric on the teazles and increases the raising action, while raising

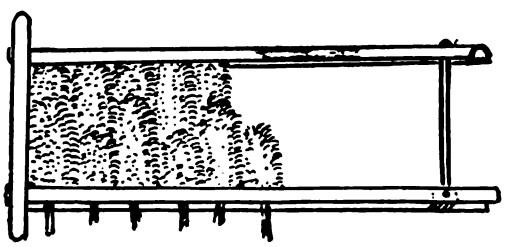

FIG. 8.—FRAME FOR CARRYING TEAZLE HEADS.

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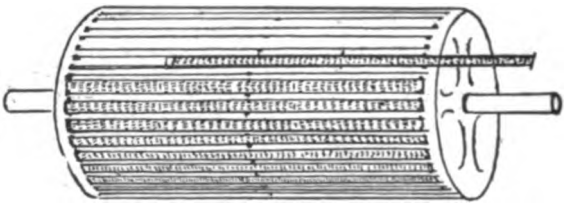

FIG. 9.—TO ILLUSTRATE METHOD OF MOUNTING FRAMES ON CYLINDER.

the roller diminishes this. The cloth, after passing round this breast roller and over the teazles, is then drawn by the rollers C over the top of the gig and the roller D, and down again to where it started. E is a lattice belt or "scray" on which the cloth falls, and this is kept gently moving by ratchets, so as to carry the folds of the cloth forward again to the cylinder.

In filling the frames with the teazle heads, or, as it is called, "setting the teazles," the first operation is to well soak the teazles in water overnight; this softens them and makes the handling much easier. After this the stems are clipped off to within about two and a half inches, by a boy technically called a "carper lad"; he then passes them on to the man who sets them. This setting used to be in itself a separate trade, and required no mean skill to fit the teazles in tightly and get them all on the same level. It will be obvious to anyone that if one teazle projects from the surface more than another it will exert more raising power, and so cause a streak in the cloth.

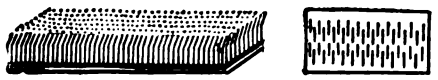

FIG. 11.—WIRE CARD.

If Fig. 8 is referred to, the method of fixing the teazles in the frame will be plain. The frame itself consists of a concave bar at the top, into which the head of the teazle is pressed, while the bottom is built of two parallel rods half an inch apart, through which the stalks of the teazles are passed. Every couple of feet a small iron crossbar is riveted, to give rigidity to the whole. It will be seen that the frames are rather wider than any size of teazle excepting the largest "kings," so that a second and smaller teazle requires to be wedged in between the first one and the rod: a glance at Fig. 8 will explain this. The projecting stems of the teazles were sliced off with a keen knife when the frame was filled. After setting, the teazles require drying to allow them to recover their normal strength and sharpness; when newly set, they are known to the trade as "breakers."

FIG. 12.—CARD-RAISING ROLLER.

Teazles are very frequently used in a wet state, particularly for very soft goods which will not stand much work. When wetted, the awn of the teazle is much more elastic and gives to the cloth instead of tearing off the wool, while on drying it regains its former shape and stiffness. The gig cylinder when full holds twenty-four frames, and it is a common thing to have frames of different strengths set

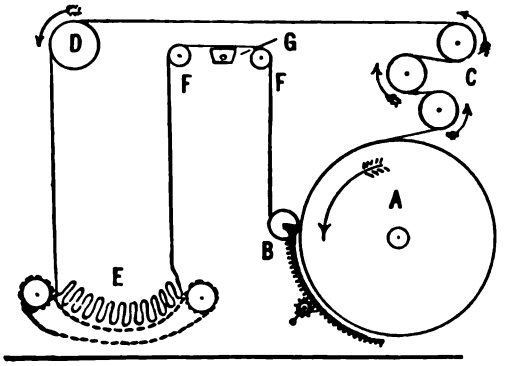

FIG. 10.—TO ILLUSTRATE METHOD OF WORKING ROTARY TEAZLE GIG.

alternately; that is, one frame set with new teazles, and the next containing "used" teazles in it. By these means any degree of sharpness or softness could be obtained, from a keen new teazle which would attack the hardest of material, to old and blunt ones which would only act as a brush.

In mills where much raising was done there were usually some hundreds of frames, all of them sorted out according to their different strengths, and forming perhaps about a dozen different grades. With some makes of cloth raising was an operation taking up not hours but days, the cloth being alternately changed first one end up and then the other. This was to ensure even raising, and to avoid streaks which were bound to develop unless the position of the fabric was changed. With this in view it was the custom to guide the cloth by hand across the face of the raising cylinder, so as to vary its position on the teazles; in recent years a patent has been taken out to attain the same end by giving the axle of the cylinder a reciprocating movement.

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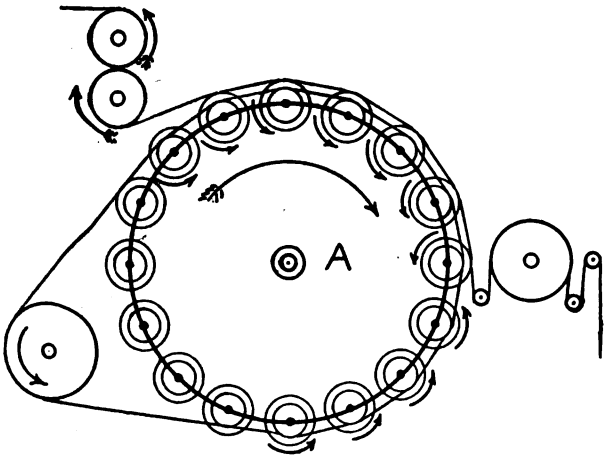

FIG. 13.—TO ILLUSTRATE ACTION OF CARD-RAISING MACHINE.

We now have to review the teazle's competitors: these are the different makes of steel and brass card and card-raising machines. *Wire* cards are not at all new, as card raising *gigs* were used forty years ago; but it is only comparatively recently that cards have been employed in a scientific manner. Before enlarging on this, a brief description of the cards themselves will be necessary; each of these consists of a short brush of steel or brass wires having a flexible backing of cotton and rubber. The combination of the two is very essential to form a good back, as while the cotton prevents stretching and loss of shape, the rubber holds the wires firm and prevents the possibility of their working loose.

Fig. 11 shows a section of card clothing and also the layers of cotton cloth and rubber at the base. The wires are U-shaped; a view of the back is given showing how they are inserted. The modern card-raising machine, which is now the teazle's most formidable competitor, is constructed on lines which approximate more nearly to the action of the teazle itself, that is, to engage with the wool and then release it rather than pull it off. The manner in which this is effected and the construction is as follows: a number of rollers about three to four inches in diameter and about seventy inches long are covered with wire cards, the card clothing being in the form of narrow ribbons which are wound on to the rollers in a spiral form (see Fig. 12). Twenty of these covered rollers are then mounted on bearings on the circumference of a large cylinder; this cylinder is then caused to revolve against the surface of the cloth, while the rollers have a contrary motion given to them by means of a pulley on each and a belt. This will be made clearer by glancing at Fig. 13, which shows the general principle. A is the large cylinder moving in the direction of the arrows, while B, B are the card rollers revolving in the contrary way (also see arrows). The rate of revolution of the small rollers can be modified to any extent, and it will be obvious that while the motion of the large cylinder causes the cards to engage with the cloth, the contrary or backward revolutions of the rollers cause the teeth to release it. The rate of backward motion given to the rollers can be increased until the raising power is nil: that is, the backward motion exactly neutralises the forward motion of the cylinder. By altering the speed of the belt which drives the small rollers, any degree of raising power can be obtained, from the most gentle action suitable for very soft goods, to the keen raising required for hard cotton material.

This is the nearest approach to the natural action of the teazle that has yet been attained; but although this machine answers admirably

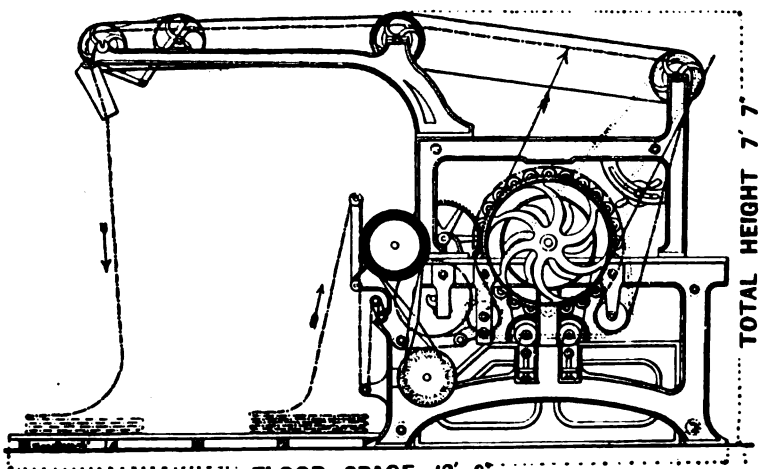

FIG. 14.—DIAGRAM OF CARD-RAISING MACHINE.

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for some fabrics, there are others which must be raised by means of the teazle. One great feature of the teazle is the minute hooks at the end of the awns; these have the property of taking hold of a single fibre and drawing it out, while the cards, not having the hooks to engage with the wool, have more of a dragging action. For the raising of plain cotton cloths into the well-known flannelette, the card-raisers are a long way the best; in fact, the flannelette trade may be said to be dependent on the action of cards to get the soft woolly nap on, which is so well known. There are several types of card raising machines, the details of which would take up too much space if gone into here. Fig. 14 is a diagram, and Fig. 18 a picture of one made by Tomlinson's, Limited, of Rochdale, to whose courtesy I am indebted for the illustrations.

The latest method of utilising the teazle is in what is known as the "spindle gig," where very delicate raising is required (see Fig. 17). In this machine the teazles are set in altogether a different way from any other raising gig. To

FIG. 15.—TEAZLES MOUNTED ON SPINDLE.

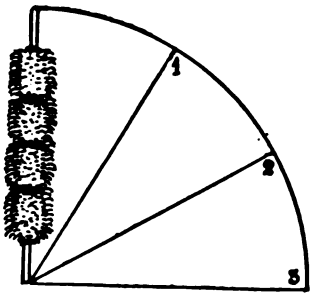

FIG. 10.—TO ILLUSTRATE RAISING CAPACITY CONFERRED BY OBLIQUE ARRANGEMENT OF SPINDLES.

commence with, the top and bottom of each teazle is cut cleanly off in the manner shown in the illustration of specimens (p. 73), where H is a teazle ready cut. After this is done the woody core of the teazle has a hole bored carefully through it, and three or four teazles are mounted on a steel spindle (see Fig. 15).

The teazles are kept in position on the spindle by means of leather washers pushed on to the spindle while wet; these contract on drying, and prevent the teazles slipping or working loose. A large number of these spindles with the teazles on are then mounted on to the circumference of a cylinder, the ends of the spindles being placed in brackets which allow them to revolve freely.

The spindles in their brackets are not arranged parallel with the axis of the cylinder, but slightly at an angle, so that while the cylinder revolves in contact with the fabric to be raised, the teazles on their spindles revolve backwards by the pressure of the cloth, and so release the wool. If the spindles were arranged perfectly parallel to

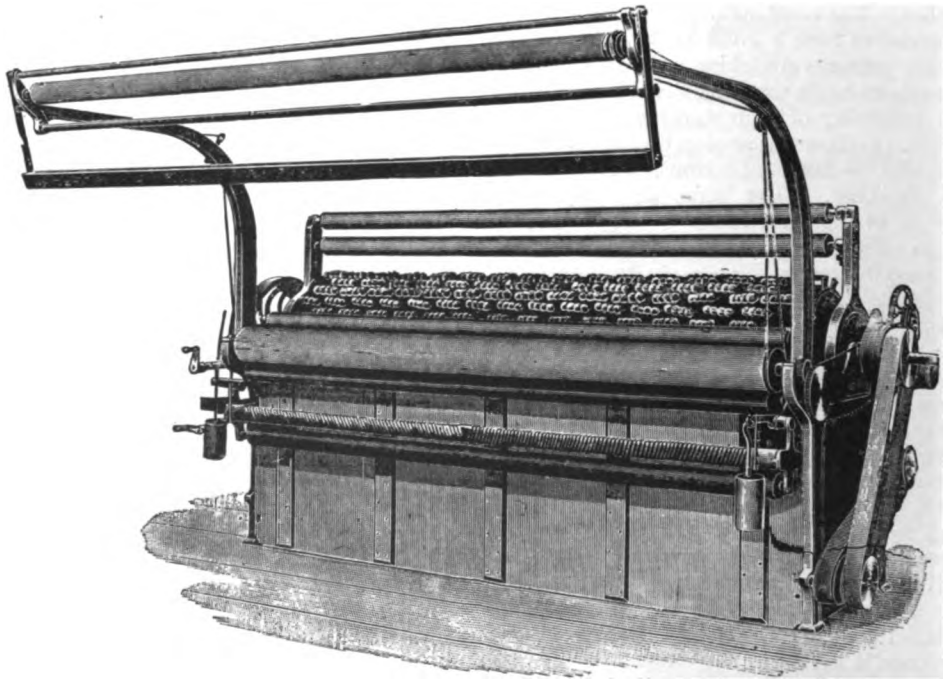

FIG. 17.—SPINDLE GIG FOR RAISING NAP OF VERY DELICATE FABRICS.

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the cylinder axis, they would have no raising power: the teazles would simply revolve without engaging with the wool in the slightest. It is the diagonal setting of the spindles which confers the raising power, and this will readily be seen by glancing at Fig. 16. This represents a spindle seen in the perpendicular; in this position the teazles are exactly in the same position as when set in the ordinary gig. This is the position for exerting the maximum raising power; if the spindle is inclined at the angles numbered 1, 2, and 3 in the diagram, the raising action diminishes as the spindle leaves the perpendicular, and vanishes altogether when it attains the horizontal at 3.

This form of machine, which is shown in full in Fig. 17, is naturally only intended for very soft material, which would easily be damaged by having the wool dragged off, and which would not be suitable for raising on the ordinary teazle gig. By varying the inclination of the spindles any gradation of slip can be given to the teazle, making it of use for the most flimsy and delicate of fabrics. With the raising of heavy cloths on the old teazle gig, water and steam played important parts, a steam box being fitted overhead (see G, Fig. 10), so that the cloth had to travel over this on its way to the teazle cylinder. By blowing steam into the fabric during working, the wool fibres were softened and the wool was kept on the cloth instead of being dragged off to make flocks. If the teazles were very sharp and keen, they were frequently wetted; this increased their elasticity and made their action on the cloth more gentle, besides helping to make them last longer. After wetting and drying the teazle will always regain its former sharpness, and if crushed will to a certain extent go back to its original shape. Unless some new mechanical device is invented, able to imitate the teazle's hook, combined with its spring and elasticity, there is little chance of it being superseded, for woollen goods at any rate.

I am indebted for the fine range of specimen teazles to the courtesy of Messrs. McLaughlin Brothers, of New York and Leeds, and for the illustrations of the three machines, Figs. 14 and 17 and 18, to Messrs. Tomlinson's, Limited, Rochdale, who are the makers.

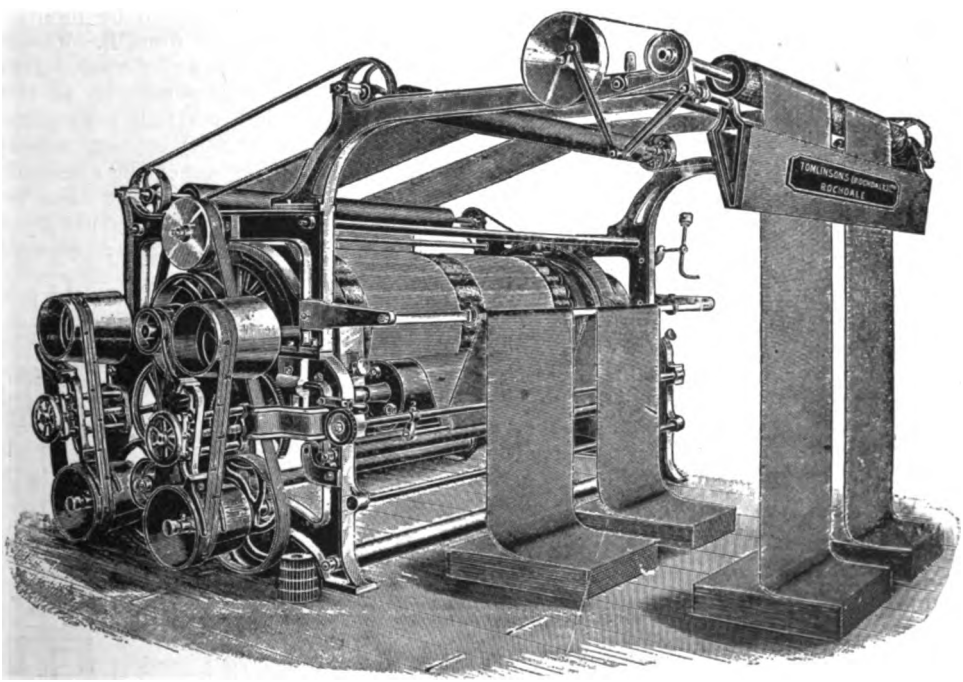

FIG. 18.—FELT-NAP RAISING MACHINE, WITH 14 ROLLERS.
The speed can be varied from 70 to 120 revolutions per minute, according to the requirements of the fabric.

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SPECIAL DEVICES USED IN WEAVING.

PART III.—ANTI-FRICTION DEVICES FOR PIRN WINDING MACHINES.

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By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

THE flattening, glazing, and sometimes abrasion of yarn constitute the worst evils, and those which are most liable to occur, during pirn winding, especially when this operation is accomplished by means of any form of metal pirn cups. Yet, notwithstanding their admitted defects, pirn cups of one form or another, and of different materials, have been in general use, probably, since the introduction of power looms, and are, perhaps, more extensively employed at the present time than all the numerous "improved" substitutions combined. This circumstance, so far from indicating either an exaggerated estimate of the serious character of those faults, or want of energy and enterprise on the part of textile machinists and inventors, serves all the more to emphasise the mechanical difficulties which the solution of those problems presents; for, perhaps, no other type of winding machine has received so much attention from inventors with a view to preventing, or at least minimising, its evil effects upon yarn. This has resulted in the invention of innumerable devices with that object. Many of these, of which some are in actual use, bear unmistakable evidence of insufficient reflection on the part of their inventors, who have attempted to solve the problem by constructing devices based on entirely wrong lines, as will be hereafter shown. On the other hand, some of them possess undoubted merit, and accomplish their object with varying degrees of success; but their cost is frequently so much greater than that of the ordinary simple pirn cup winding machine, as to prevent their general adoption; and many manufacturers prefer to submit to the inconveniences of imperfect machinery and appliances, when they would willingly incur any reasonable expenditure for improved machinery that would ensure superior results without materially increasing the cost of production.

Before investigating those special devices, it will be helpful to briefly consider the action of an ordinary pirn cup winding machine, as illustrated in Figs. 9, 10, and 11, to better understand the causes of the evils usually associated with it. In such a machine, bobbins are built up with yarn as they revolve within cast-iron pirn cups H, having a very smooth interior surface in the form of a cone that is counter to that of a bobbin head. A pirn cup is represented in Fig. 12, where A is a front, B a side, and C a plan view. Bobbins G are rotated at a uniform velocity by means of spindles E, surmounted with a heavy head-piece F, furnished on the underside with two projecting lugs, that fit in a groove formed in the bobbin head. The lower half of spindle shanks, which are rectangular in cross-section, are inserted in rectangular holes, passing centrally through wharves D, which are driven by means of cotton bands C and a tin drum B. Threads pass over guide rails T, and through vertical gaps formed in the pirn cups, on to their respective bobbins. Guide rails T are caused to rise and fall at a slow uniform velocity, whereby yarn is coiled between the extremities of a bobbin cone in a close spiral formation. Guide rails are variously controlled in different machines. In the machine here represented, they are actuated by means of a grooved cam L, fixed upon a short side shaft K, to which is also secured a worm wheel I, gearing with, and driven

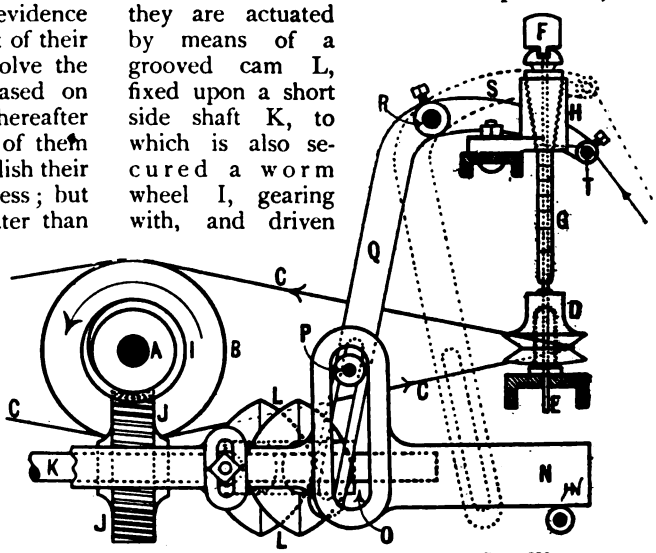

FIG. 9.—PART END ELEVATION OF A PIRN CUP WINDING MACHINE.

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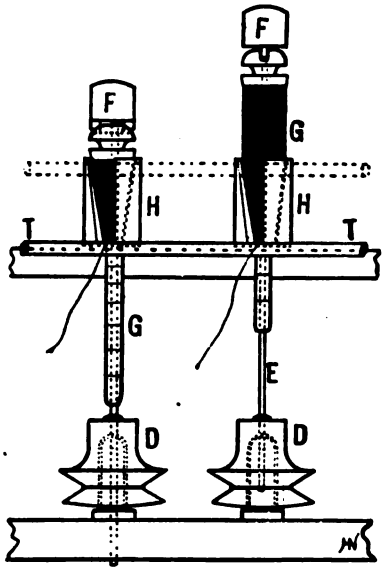

FIG. 10.—PART FRONT ELEVATION OF A PIRN CUP WINDING MACHINE.

by, a worm J, fixed at one end of the tin drum shaft A. The cam acts upon a runner M, carried by a stud fixed to a sliding rail N, to which is imparted a lateral reciprocal motion. Two vertical slots O, formed one on each side of the sliding rail N, act upon a runner P, secured to an arm Q, set-screwed to the end of a rod R, which extends for the whole length of the machine, and on which are fixed, at intervals, a number of brackets S, to support the guide rail T. Thus, as cam L revolves, guide rails T rise and fall alternately, in a manner determined by the formation of the cam.

As winding proceeds, yarn is placed in a series of successive conical layers, each one being placed over the preceding layer, but a little further removed from the bobbin head. In consequence of yarn passing on to a bobbin as it revolves within a confined conical chamber, the bobbin and its spindle are gradually forced upward by the resistance of the pirn cup as successive layers of yarn are added; and herein lies the cause of yarn becoming glazed and flattened by its constant friction and pressure against the side of the cup. With most pirn winding machines, a certain amount of pressure, as well as tension of yarn, is necessary during winding, to ensure yarn being wound with a sufficient degree of compactness; otherwise, if it is wound too soft, it will be liable to break bodily asunder by the concussion of a shuttle during weaving; on the other hand, if too much pressure is applied to yarn, it will increase its frictional resistance against the pirn cup, and accentuate the evils named.

The tendency of yarn to glaze or burnish varies according to circumstances, and is greater with yarn dyed in the more sombre tones of colour, and with the less soluble dyes, which leave it somewhat harsh and rough. Even when the weight of a spindle is such as will scarcely ensure the requisite degree of compactness of yarn, the frictional resistance of the latter against the pirn cup is sometimes so excessive as to cause its abrasion. The effect of "shaded" and glazed yarn in cloth is so objectionable that pirn bobbins are sometimes "boxed," *i.e.*, assorted into three or four lots, before being supplied to weavers. Those which are least affected are used for superior qualities, and those most affected for inferior qualities of cloth.

Various methods have been devised with a view to preventing excessive friction upon yarn during winding. Pirn cups constructed of glass have been tried without success, and cast-iron cups enamelled and glazed on the inside have been equally unsuccessful. This would appear to show conclusively that rigid and stationary cups of any material are un-

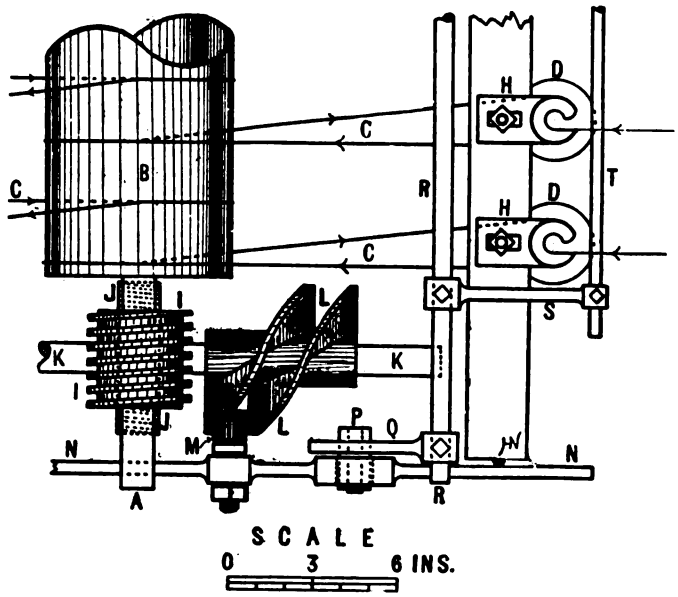

FIG. 11.—PART PLAN OF A PIRN CUP WINDING MACHINE.

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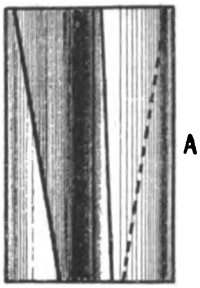

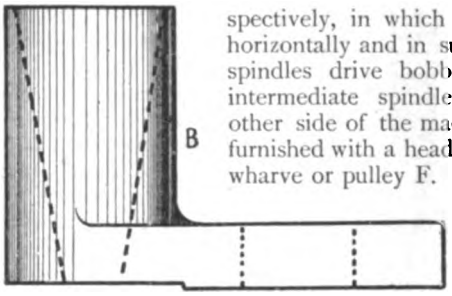

spectively, in which spindles G are arranged horizontally and in such manner that alternate spindles drive bobbins I on one side, and intermediate spindles drive bobbins on the other side of the machine. Spindles are each furnished with a headpiece H, and an elongated wharve or pulley F. A headpiece is provided with two lugs that fit into a groove formed in a bobbin head, and also with a short pin that enters a bobbin and ensures the latter properly centering upon its spindle as it revolves within a pirn cup J. Long wharves are fixed upon spindles to permit of their recession, and yet retain their driving bands E, as bobbins

suitable. This conclusion appears to have been acted upon by the designer of Boyd's pirn winding machine, illustrated in Figs. 13 and 14, which show an end elevation and part plan of that machine, re-

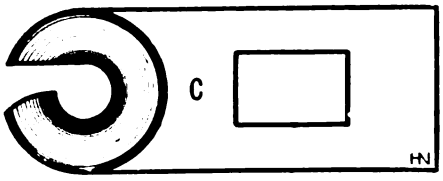

FIG. 12.—PIRN CUP.

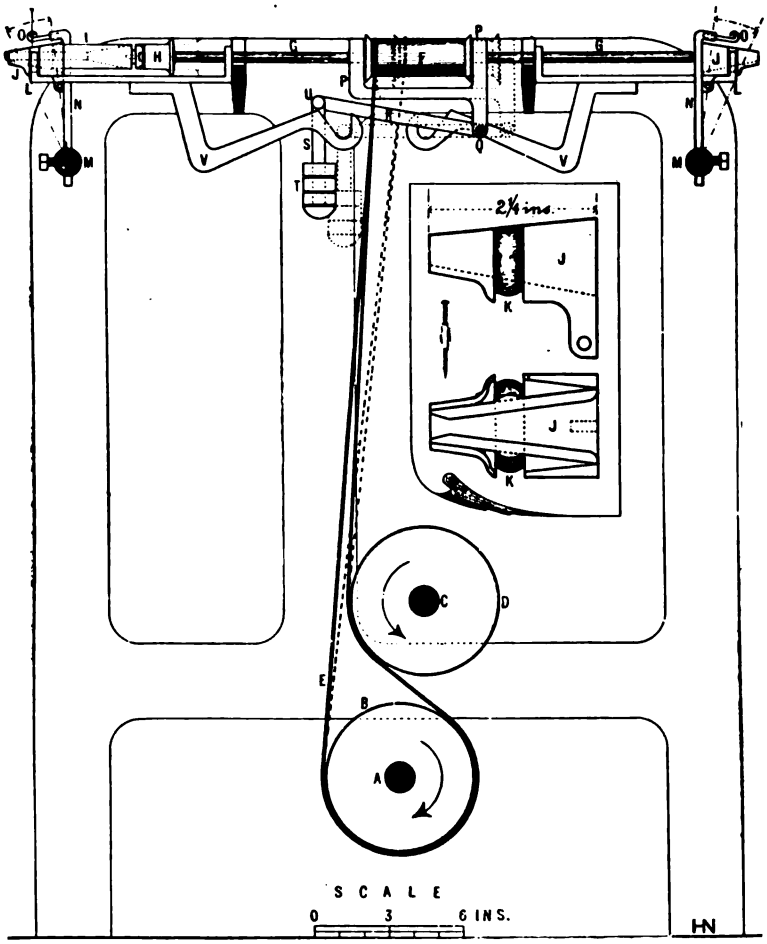

FIG. 13.—END ELEVATION OF BOYD'S PIRN WINDING MACHINE.

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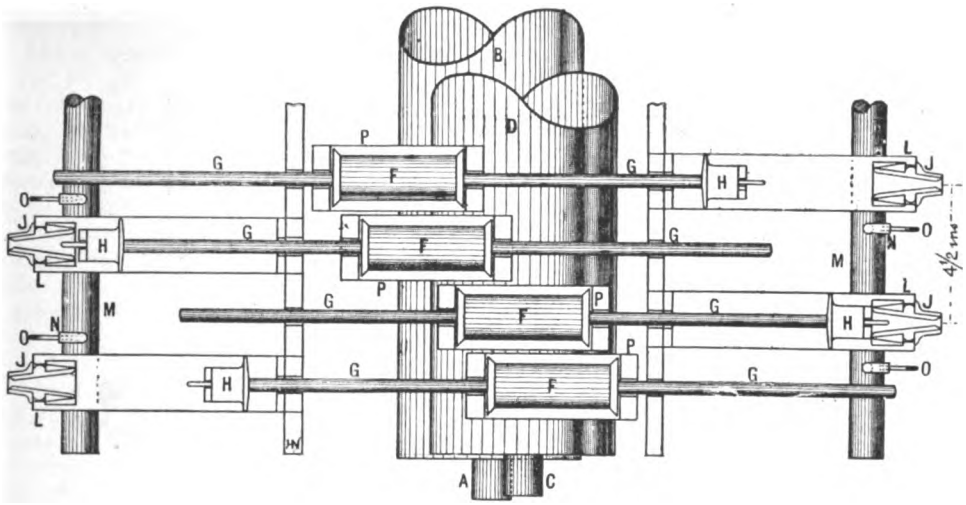

FIG. 14.—PART PLAN OF BOYD'S PIRN WINDING MACHINE.

fill with yarn. The driving bands E transmit motion to spindles G from a tin driving drum B on shaft A, which also contains the driving and loose pulleys. An auxiliary tin drum D, on shaft C (which is positively driven by tooth gearing, from shaft A), serves to increase the driving efficiency of the bands by increasing their arc of contact with drum B, and also by its direct influence upon them. Wharves F are each situated within a frame or carriage P, which moves laterally with its spindle. The rear end of each frame carries a pin Q, which serves both as fulcrum and connecting point for an arm R, from the free end of which depends a rod S, on which are placed small weights T. As a spindle and its carriage recede, a cross-piece U, on rod S, slides up long inclined brackets V, until it reaches the summit (by which time a bobbin is full), when it slides quickly down to the bottom of the short incline (as indicated by dotted lines), thereby carrying the spindle backward and releasing it from the filled bobbin, which automatically stops, although the spindle continues to revolve. To start a fresh bobbin an operative raises arm R, and pulls it forward to bring up a spindle to the bobbin. A spindle is temporarily stopped by gripping its wharve to permit of the headpiece H being inserted in a bobbin head. By increasing or reducing the number of weights T on rod S, a greater or lesser degree of pressure may be applied to bobbins during winding, to suit the varying requirements of different kinds of yarn.

A distinctive feature of this machine, and

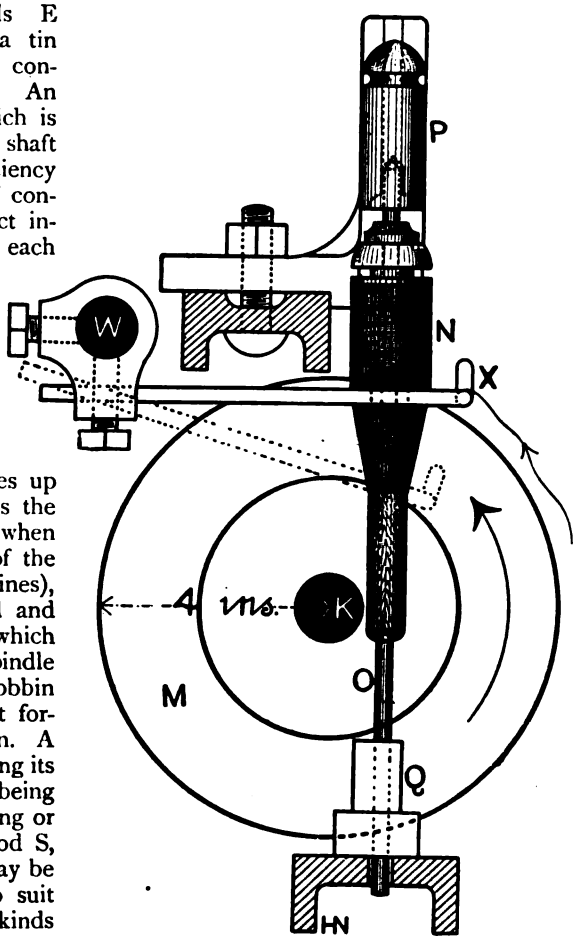

FIG. 15.—PART END ELEVATION OF HACKING'S DISC PIRN WINDING MACHINE.

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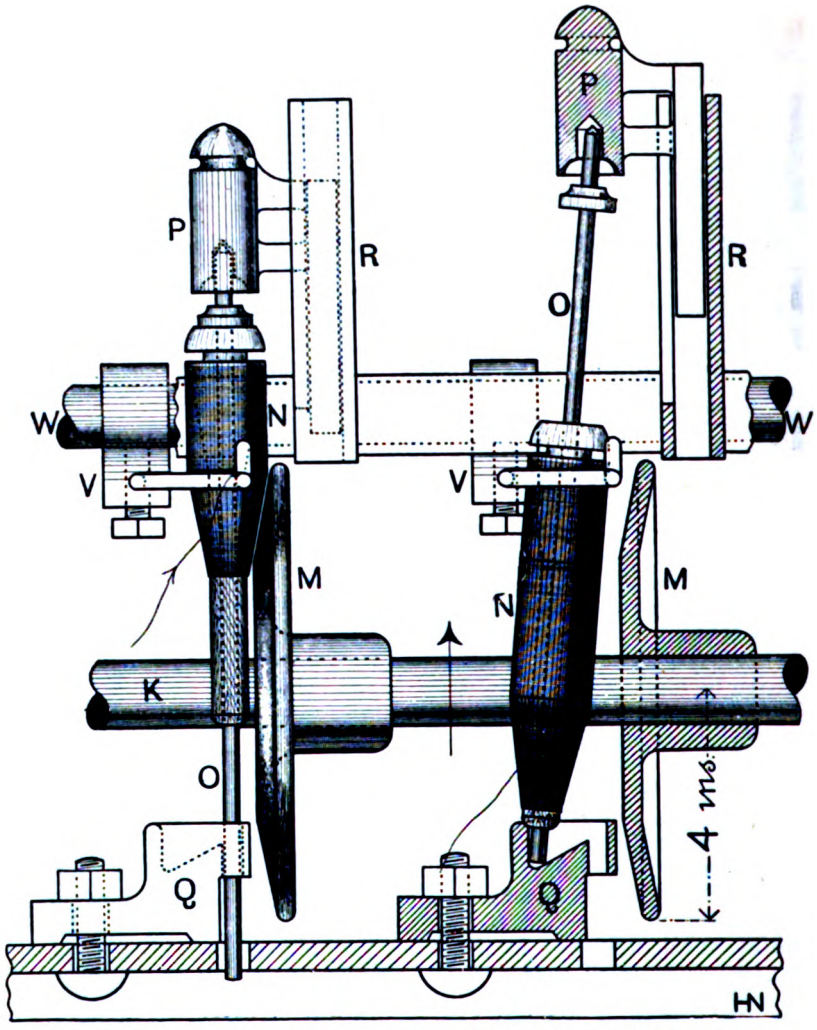

FIG. 16.—PART FRONT ELEVATION OF HACKING'S DISC PIRN WINDING MACHINE

one which gives superior results to those usually obtained in an ordinary pirn winding machine, is the method of supporting the pirn cups J, which are of cast iron. An enlarged side and plan view of a pirn cup are shown in the inset, in Fig. 13. Instead of fixing the cups rigidly, they are freely supported in frames L, which span an outer groove K, formed in each cup to hold them in position. This ingenious method of retaining cups gives them a certain degree of flexibility in their supports, and permits of their readily yielding to any side pressure that may arise from such causes as imperfect alignment of spindles and cups, crooked bobbins, or other irregularity; whereas, in an ordinary pirn winding machine with fixed cups, if the centres of cups and wharves are not in perfect alignment, or if spindles are slightly bent, as they are so liable to become, bobbins do not bear evenly against the cup sides, but bind more or less to one side, with injurious effect. Another favourable circumstance, which tends to minimise the glazing of yarn, is afforded by the horizontal arrangement of spindles, whereby the gradually increasing weight of a bobbin, as it fills with yarn, does not cause additional pressure of yarn against the pirn cup (as it does when spindles are vertical, as in an ordinary pirn winding machine), but maintains a uniform pressure throughout. This may appear a trivial matter, but when one is striving after perfection, details may not be lightly ignored. It has been well said

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that "trifles make perfection; and perfection is no trifle."

Many inventors have sought to avert the evils of pirn winding by discarding the stationary cups in any of their forms, and substituting anti-friction devices in the shape of either bevelled discs, or conical bowls or rollers, against which bobbins revolve, so as to provide a rolling, instead of a stationary surface contact with yarn. These devices have assumed various forms, and in one form or another they appear to give better results than are generally obtained by the use of pirn cups. Still, although the principle of a rolling contact may be good, it is frequently misapplied. Some machines are constructed to drive bobbins by their surface contact with either driving discs or driving bowls; whilst in others, bobbins are driven in the usual manner by means of a tin drum, cotton bands, wharves, and spindles, whilst bevelled discs, or conical rollers, are employed to merely serve the function of a pirn cup to bolster up bobbins, and shape them. But, whatever form these anti-friction devices may take, and however they may be applied, their success entirely depends upon the surface velocity of a disc or bowl, and a bobbin cone, exactly coinciding at all points of their contact with each other. This may only be secured by shaping the discs or bowls so that their circumferences vary in exactly the same ratio as that of a bobbin cone, along their line of contact. It is because this condition is only approximately secured, and in many cases actually reversed, that anti-friction devices frequently fail to accomplish the object for which they were designed.

Figs. 15 and 16 show a side and front elevation, respectively, of parts of a bevelled disc pirn winding machine made by Hacking & Co., and is the same machine as that to which is applied the differential driving motion represented in Fig. 6, which appeared, and was described, in the December issue of TECHNICS. In this machine, it will be remembered, bobbins N are driven by surface contact with bevelled discs M, fixed upon driving shafts K. A bobbin is firmly held against a disc by its spindle, which is supported at the top by a head-piece P, and at the bottom by a bolster Q. As a bobbin fills with yarn, it is forced upward automatically by the resistance offered by a disc. It is evident, therefore, that whilst allowing for a certain amount of frictional resistance of a bobbin against its disc, the amount will be small in comparison with that of a stationary pirn cup. Nevertheless, this machine is sometimes productive of both glazed and flattened yarn. The tendency to these defects may arise from two causes, namely, (1), the frictional resistance of a spindle in its bearings in the head-piece and bolster; and (2), the position of a spindle in relation to a disc, whereby the axis of the former is situated out of the centre of the latter (so as to get a spindle and bobbin clear of the driving shaft K) instead of being radial to it. Consequently, as a disc revolves, it exerts a slight rubbing action upon yarn, and tends to lift a bobbin instead of rolling freely against it.

(*To be continued.*)

ERRATUM.—In TECHNICS, Vol. II., No. 11, November, 1904, p. 484, seventh line from bottom of first column, for "velocity of spindles" read "velocity of bobbins."

A NEW INVERTED GAS BURNER.

THE latest addition to the rapidly swelling host of inverted burners is the K burner, which has just been put on the market by Messrs. Moffat's, Ltd., of 155, Farringdon Road, E.C. The object aimed at in the design of this burner is to secure a high velocity of gas flow together with a pure air supply. The air is not admitted to the Bunsen tube immediately above the burner, where it would be vitiated by mixture with the waste gases from the flame, but at orifices in a horizontal arm extending to some distance from the burner. The air intake is direct and unimpeded, and the downward flow in the Bunsen tube is relatively short, so that a high velocity is imparted to the mixture of air and gas, thus improving the light and preventing "striking back." The light emitted is of about 90 candle-power. By a ruthless elimination of all unnecessary details, the cost of the burner has been reduced to a very low figure, while nothing is sacrificed as regards efficiency.

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INSULATION AND INSULATORS.

By HAROLD D. SYMONS.

Paper read before the Students' Section of the Institution of Electrical Engineers, April 27th, 1904.

PART I.—INSULATION.

THE question of insulation is one of tremendous importance, although very little attention seems to be paid to it by engineers; the amount of literature on this subject is small, and manufacturers of insulating compounds experiment with various materials, but do not publish their results. This retards progress considerably, as many are probably going over the same ground as that covered by others, and making the same errors: the only remedy to this unfortunate state of affairs would seem to be the revision of our patent laws, as there is not much doubt that many insulators and methods of manufacture are not patented for fear of the ease with which the penalties of infringement can be evaded, and with those that are patented the specification is often very different from the article as placed on the market.

The essential features of dielectrics for different purposes vary considerably; but it may be summed up that a good dielectric should have:—

1. High puncture resistance.
2. Good insulation resistance.
3. Low specific inductive capacity.
4. Flexibility.
5. Must not absorb moisture.
6. Mechanical strength.
7. Must not contain air holes.
8. Withstand variations of temperature.
9. Should be chemically inert.
10. Should not be brittle.
11. Preferably should not be inflammable, and be unaffected by acids or alkalies.
12. Should remain permanent as to its electrical properties.

With telegraph cables puncture resistance is not necessary, nor is it essential that they should withstand high temperatures; it is not an advantage to have too high an insulation resistance, as if this is low the leakage currents tend to wipe out the effect of inductive capacity and help to make signalling more rapid. The inductive capacity, however, should be low: this latter remark also applies to telephone cables.

It is questionable whether it is advantageous to have either a high or low inductive capacity for power cables, but whichever is most advantageous, it should remain constant; should a cable vary considerably in inductive capacity after laying, it is probably an indication that the dielectric is absorbing moisture.

High puncture resistance or disruptive strength is a very necessary quality in a dielectric. The best analogy to it is that of a loaded beam; a beam may be so loaded that it breaks down immediately on the stress being applied, or withstands the strain for some time before breaking down: with a loaded beam the breakdown is caused by mechanical rupture, whereas with dielectrics which are punctured by a certain voltage, the breakdown is more often due to a

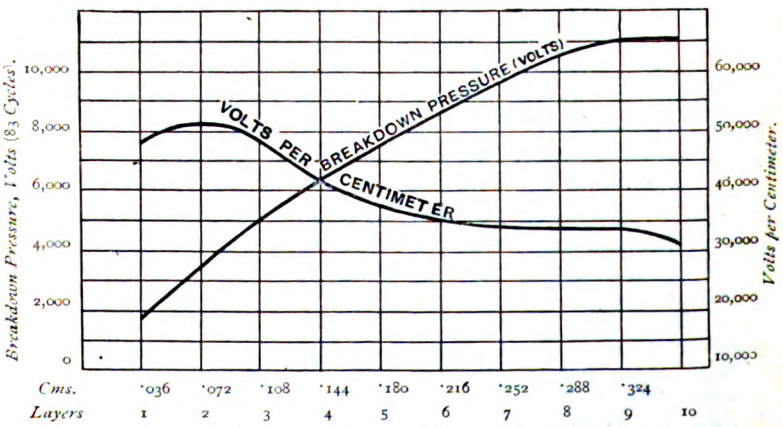

FIG. 1.—"BERRITE" FABRIC NO. 1.

Disc Electrodes. Temperature 15°C. Wave form, nearly Sine Curve.

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charring of the material than to mechanical rupture. Some dielectrics, when punctured, seem to give way by actual disintegration; this usually shows, however, that the material is not of a homogeneous character.

High puncture resistance is by no means an inherent quality of dielectrics; a cable may have a good insulation as regards its ohmic resistance, but a very low disruptive strength: to obtain high disruptive strength the specific inductive capacity must be homogeneous throughout the dielectric, as particles of higher specific inductive capacity in a matrix of lower specific inductive capacity tend to set themselves in the plane of highest potential slope, and produce a fault under high potential stress. This is not a hard-and-fast rule, as a dielectric may contain a very small percentage of a substance of a different specific inductive capacity without affecting its disruptive strength; this, however, depends upon the relation of one to the other: Mr. O'Gorman's method of grading the inductive capacity of a cable dielectric was to reduce the extreme straining of the insulation of a high voltage cable, as for any definite-sized conductor it has been found impossible to increase the puncture resistance of the cable beyond a certain point, no matter how much extra thickness is added.

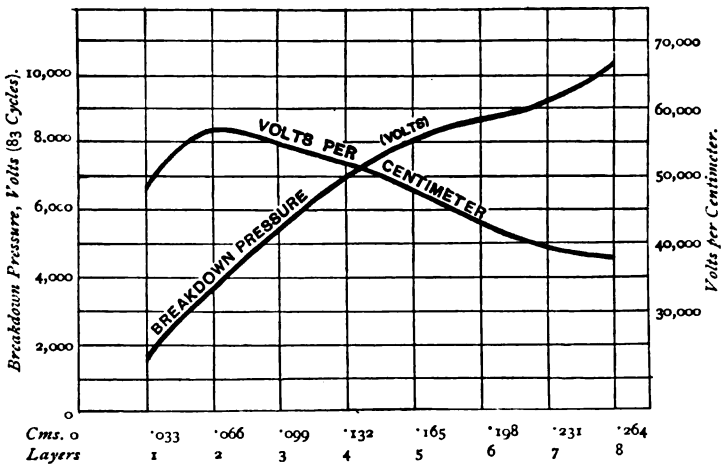

FIG. 2.—"BERRITE" FABRIC NO. 2.
Disc Electrodes. Temperature 17°C. Wave form, nearly Sine Curve.

If mica be covered with a layer of any insulating oil, its puncture resistance is reduced considerably. This is not because of the difference of the specific inductive capacities, but for quite another reason: the oil under the electrodes has a lower disruptive strength than the mica, and breaks down first; at the point where the oil breaks down it carbonises, becoming a conductor for the time being, and intensifies the electrical stress on the mica just at the point where the oil has broken down, and the mica punctures at a very much lower voltage.

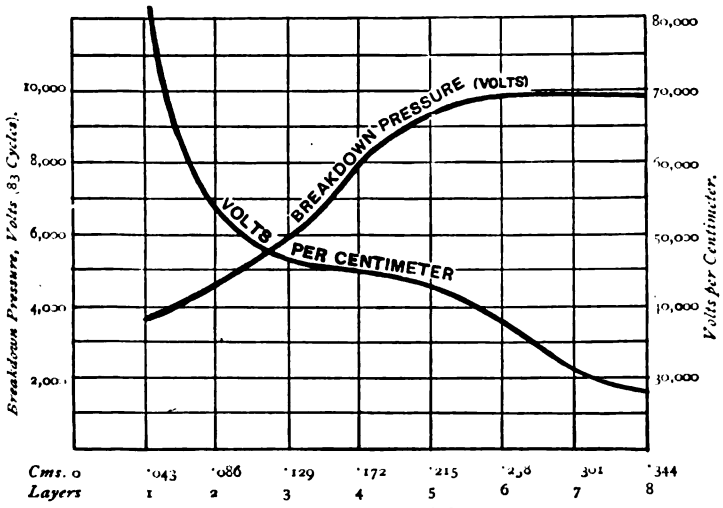

FIG. 3.—BERRITE" B
Disc Electrodes. Temperature 17°C. Wave form, nearly Sine Curve.

It is for the very same reason that press-spahn has a higher puncture resistance than press-spahn with a coating of insulating varnish. Many manufacturers of dynamo electric machines are at a loss to understand why this is so, whereas, on applying the same insulating varnish to cotton, tape, or paper, the puncture resistance is increased. Cotton, tape, and paper are much more hygroscopic than press-spahn, and the insulating varnish enters into the small air holes and capillary tubes, rendering them non-hygroscopic, thereby increasing

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the puncture resistance, and making them less likely to absorb moisture; coating press-spahn with an insulating varnish renders it less likely to absorb moisture, but reduces the puncture resistance. The author, in carrying out some puncture resistance tests on various dielectrics, pasted tinfoil on either side of the specimens, and found that this apparently reduced the disruptive strength enormously; but the dielectrics broke down at approximately the same voltage as they did when tested between a plate and a point, thus helping to prove what has been stated above.

The actual break-down point, however, is very difficult to determine; the puncture resistance will vary with:—

1. Frequency.
2. Temperature.
3. Shape of wave.
4. Nature of electrodes.
5. Length of time pressure is applied.

In every series of tests, the above particulars should be given; the wave form should be a sine curve, and the electrodes plates, but slightly curved at the edges, to prevent undue stress produced by a sharp edge; the pressure of the plates on the dielectric does not apparently affect the result.

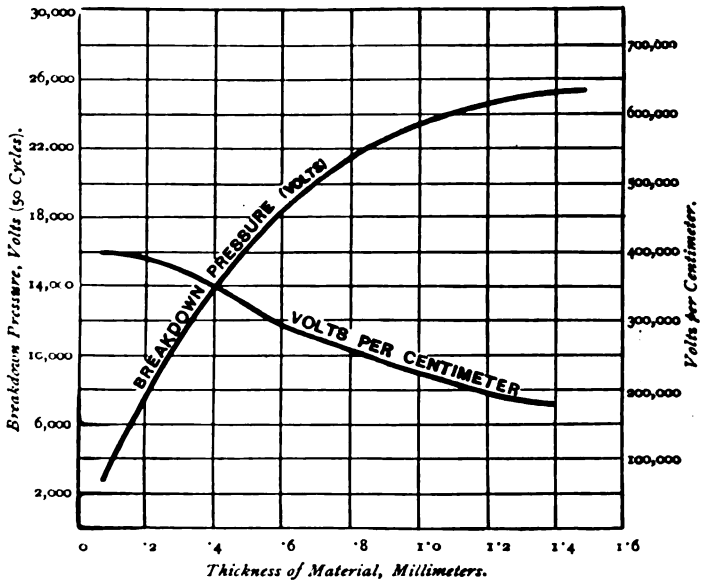

FIG. 4.—BRIGHT YELLOW OILED CLOTH NO. 1.

Many dielectrics, if maintained at a voltage slightly lower than that at which they break down immediately on the pressure being applied, will break down at the lower voltage if this is maintained for a few minutes. The author is of the opinion that the actual break-down voltage should be that which punctures the material immediately on being applied; in making such a test it may, of course, happen that the voltage might just be applied at the instant when it is at its maximum value; but a series of tests should be made to determine the exact voltage; this would help to make tests on various dielectrics more comparable, but it is, and always will be, difficult to obtain the same break-down point for two samples of the same material; this is probably due to the fact that no two samples are homogeneous throughout.

That this is so is shown by the fact that, with a dielectric of high puncture resistance, as the break-down voltage is approached there will be more or less surface leakage; and the

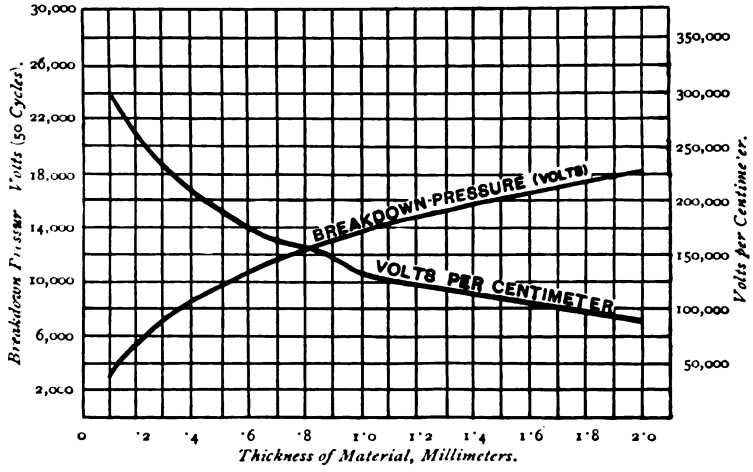

FIG. 5.—BRIGHT YELLOW OILED CLOTH NO. 2.

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dielectric sometimes breaks down at a place some considerable distance from the plates, there being a weak spot which gives way under the stress before the potential difference is high enough to puncture it between the plates.

This surface leakage undoubtedly adds uncertainty to the results, but it is difficult to see how it can be avoided; it has been advocated by some experimenters that the puncture resistance should be taken with the electrodes and dielectric immersed in oil; this prevents surface leakage, but it is not testing the dielectric under working conditions, and it is almost a benefit that dielectrics have this surface leakage, as it may in some cases prevent breakdown.

Messrs. Canfield & Robinson (see Elec. Eng. N.Y., Vol. XVII., p. 280) suggest that the dielectric and plates before test should be immersed in hot paraffin wax, then removed and tests carried out as soon as the wax has set; this also prevents surface leakage, but the hot wax may have an injurious effect upon the dielectric.

The following table is taken from the results of their tests, thus carried out on mica; as will be seen, it does not seem to make their results more uniform, and for the reason already suggested, it is possible that surface leakage may be an advantage rather than not.

	Thicknesses.	E.M.F.
Mica, without paraffin wax	1·9	3,200
,, ,, ,, ,,	3·4	7,600
Mica, with paraffin wax	1·7	5,000
,, ,, ,, ,,	2·	5,700
,, ,, ,, ,,	2·7	5,900
,, ,, ,, ,,	3·2	6,200
,, ,, ,, ,,	3·4	6,800
,, ,, ,, ,,	4·6	4,800
,, ,, ,, ,,	5·1	6,100

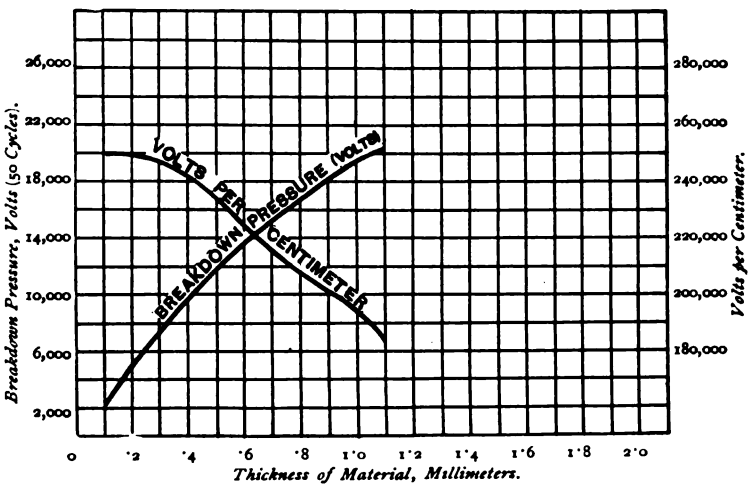

FIG. 6.—"PRESS-SPAHN" SAMPLE NO. 1.

Increase of frequency would seem to produce an increase of puncture resistance, dielectrics under high frequencies not breaking down as with lower frequencies of the same potential; this may be due to a difference in the wave form, a "peaky" wave being more liable to pierce a dielectric than a sine wave: break-down tests with induction coils or Wimshurst machines are not of much value, a transformer being far preferable, as it is possible to actually obtain a "power" discharge.

Increase of temperature of fibrous materials and oils increases their disruptive strength within limits, the moisture they contain being gradually driven off; it cannot be said, however, that this is the case with all dielectrics, and certainly not with many impregnated materials, where heating means that impregnating compounds will tend to leave the material: speaking generally, it may be said that increase of temperature decreases puncture resistance.

High temperature, if continued for some considerable time, may have a very serious effect on insulators, as it will tend to disintegrate them. C. E. Skinner, in a paper before the American Institution of Electrical Engineers,* very clearly shows that considerable damage may be done to a dielectric by subjecting it to a high alternating potential stress, without any signs of the damage done being apparent: with all tests on dielectrics for disruptive strength, the plates should have a diameter very much larger than the thickness of dielectric under test, so that the area of potential stress is large, and the distribution of electricity on the inner surfaces

* See Transactions American Institution of Electrical Engineers, Vol. XIX., p. 1,047.

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of the plates uniform; if this is not so, discrepancies may occur, due to increase of stress.

As to what law insulators follow with regard to the increase of puncture resistance with increasing thickness, is by no means certain: many are the experiments which have been carried out to determine this, but no one seems to have arrived at any very definite conclusions. The author has also carried out a great number of tests with varying thicknesses of dielectric, more especially with the insulators now on the market (see Figs. 1 to 7).

With curves Nos. 1 to 7, however, the increasing thickness was obtained by placing several layers together; and although they were very tightly compressed, still there must have been a thin film of air between each layer, which of course does not make these tests absolute. These results are from tests made with plates, the puncture resistance being that at which the substance broke down immediately on the e.m.f. being applied; the actual voltage at break down varied a little, but the curves are from the mean of about half-a-dozen tests of each thickness.

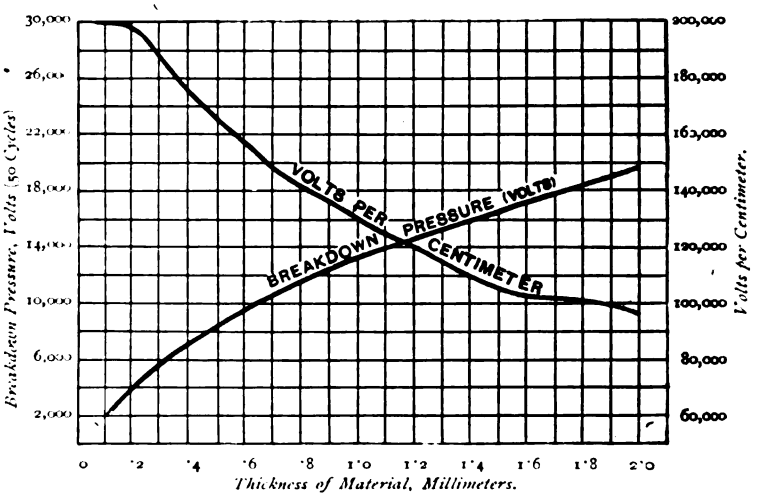

FIG. 7.—"PRESS-SPAHN" SAMPLE NO. 2.

Dr. Walter, in a series of experiments to determine the law insulators obey with regard to their puncture resistance with increasing thickness, used a plate and point as electrodes, in conjunction with an induction coil, making about twenty breaks a second, and obtained straight line laws.

His results are of extreme interest, and he suggests that all break-down tests should be carried out in a similar manner to his: this, however, would not be of great use, as it is not testing the dielectric under working conditions, and it would be very difficult to determine the ratio of the strain under these conditions, to that of the same voltage with a sine wave; there would also be some difficulty in measuring the high voltages, and as before stated, it is impossible with an induction coil to realise a power discharge.

The author is of the opinion that the discrepancies in the results of different people's tests are due to the dielectrics not being of a homogeneous character, but that if samples of varying thicknesses of a material could be obtained perfectly homogeneous, and their dielectric strengths measured in the manner indicated in the paper, it would be found that up to a certain thickness the increase of disruptive strength with increasing thickness would follow a straight line law. After this point, surface leakage would be considerable and the curve would bend over, but if surface leakage could be eliminated, the straight line would continue for some considerable distance further, and then become a parabolic curve: the thickness of dielectric at which the straight line law will cease will depend on the voltage which will be required to produce puncture, and at which surface leakage begins to play an important part.

The author has also endeavoured to carry out tests on various thicknesses of the same materials, but has been unable to break down samples of any great thickness, as his resources only allow of his reaching a maximum of 25,000 volts, and this has been found quite insufficient.

(*To be continued.*)

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REVIEWS.

Electricity and Magnetism: An Elementary Text-Book, Theoretical and Practical. By R. T. Glazebrook, M.A., F.R.S., Director of the National Physical Laboratory. pp. viii. + 440. (London: C. J. Clay and Sons. 1903.) Price 7*s.* 6*d.*

This book has been written for those commencing the study of electricity and magnetism. The style is concise and lucid, the diagrams are admirably adapted to the elucidation of the text, and no point of importance which should be understood by the elementary student has been omitted or slurred over. It is to be regretted, however, that the author has not given the reader the means of deciding between the contact theory and the chemical theory of the E.M.F. of a cell. According to the contact theory, the seat of the E.M.F. of the cell is the junction between the zinc negative electrode and its copper connecting wire; on the chemical theory the seat of the E.M.F. is at the point or points where chemical energy is transformed into electrical energy—*i.e.*, within the cell itself. Everyone interested in obtaining clear ideas on the electric circuit must feel deeply indebted to Sir Oliver Lodge for the lucid manner in which he has argued this disputed point. If the seat of the E.M.F. is at the zinc—copper junction, the electrical energy is generated at this junction when the current flows across it in the direction *zinc—copper*; and a corresponding amount of electrical energy must disappear, being changed into some other form, when the current is sent across the junction in the direction *copper—zinc*. There is no evidence of any chemical action at the *copper—zinc* junction, so that the only form into which the electrical energy could be charged appears to be heat; experiment shows that the heat produced at the junction is of quite a different order of magnitude from that required to account for the E.M.F. of the cell. Hence it appears that the seat of the E.M.F. of a cell is within the cell itself, where the chemical changes occur. Of course pieces of zinc and copper, when placed in contact in air, are found to acquire electric charges; Sir Oliver Lodge very reasonably argues that they should not be considered to be at different potentials. Numerous experiments have been undertaken in order to show that, in a perfect vacuum, no electrical charges would be produced when pieces of zinc and copper are touched together; but it is impossible to obtain a vacuum anything like good enough to settle this point. Brown, of Belfast, however, has shown that if the metals are placed in contact in sulphuretted hydrogen, the electric charges produced are different from those obtained when the experiment is performed in air; this result gives support to the theory that the charges are produced by chemical action on the two metals. Although it has been found impossible to obtain a complete vacuum (*i.e.*, a free space absolutely devoid of gaseous oxygen), yet the matter has been settled in another manner. It has been found that if the metals are placed in contact beneath paraffin oil, or any similar non-conducting liquid in which water does not dissolve, then no charges are produced: this result appears to satisfactorily settle the vexed question in favour of the chemical theory advocated by Sir Oliver Lodge.

Carpet Manufacture. By Fred Bradbury, Head Master of the Textile Department, Municipal Technical Institute, Belfast. pp. 301, with three coloured plates and 240 other illustrations. (Published by the Author, Municipal Technical Institute, Belfast, Ireland. 1904.) Price 10*s.* net.

In view of the importance of the "Carpet Industry," it is strange that no work dealing with the technicalities of this industry has hitherto been published. As it is, Mr. Bradbury's book occupies quite a unique position in having no competitors. It is impossible to praise too highly the way in which the task of writing the book has been discharged. The author has come into practical touch with almost every detail of machinery described in the book, and the illustrations have been selected from machinery in present use. The carpet and rug patterns illustrated in the plates have been designed and woven under the author's supervision at the Municipal Technical Schools, Halifax. The arrangement of the book is excellent, and no pains have been spared to render the illustrations as clear and instructive as possible.

A New Geometry for Schools. By S. Barnard, M.A., and J. M. Child, B.A. pp. xxvi. + 514. (London: Macmillan & Co. 1904.) Price 9*s.* net.

This volume represents an attempt to produce a text-book of Elementary Geometry, complete in every detail, and suitable for many classes of students. Thus, while due consideration is given to the theoretical aspects of the subject, attention is also devoted to practical applications. The first section of the book is devoted to preliminary definitions and explanations. The second section is practical in character, and contains, amongst other valuable matter, those parts of Trigonometry which are of most value to the student. The third section is theoretical, and contains an excellent substitute for Euclid on modern lines. Altogether this is a most useful book, and it is sure to be popular.

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ANSWERS TO QUERIES.

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

TEXTILE DESIGN.—Give design, proportion of warp and weft, and colours or schemes of the following cloths, viz.: 1, Zibeline; 2, Oriental cord; 3, Bamboo cord; 4, Mistral voile; 5, Estamene; 6, Chevron.

All these terms describe different varieties of worsted dress fabrics.

1. *Zibeline* is a variety of fabric characterised by a fairly long nap, which imparts a hairy appearance to the cloth. The nap is produced on the face side of the fabric on which it lies flat, and in one direction only, namely, in the direction of warp-ends, or lengthwise of the piece. Zibelines are produced in both the plain or tabby weave, and in twill weaves. Some are piece-dyed in various hues, after weaving; and others are produced from yarn spun from variously coloured fibres that have been blended previous to spinning, so as to create a mingled colour effect in both yarn and cloth.

An example of Zibeline of fairly heavy texture of the plain weave, for winter wear, contains 30 warp-ends of 2/16° blended yarn, and 26 picks of the same kind of yarn, per inch. Another example, of light texture of the four-end ($\frac{2}{2}$) twill weave, for summer wear, contains 60 warp-ends of 70°, and 48 picks of 15° yarn, per inch, and is piece-dyed a maroon hue.

2 and 3. *Oriental and Bamboo Cords.*—The terms Oriental and Bamboo have no technical signification, but are merely employed as fanciful trade-names for sale purposes, and to distinguish the goods of one merchant from similar goods of other merchants; hence, similar fabrics are frequently sold under different trade-names in different establishments and towns. Fabrics of this class are piece-dyed in various hues, and distinguished by a fine corded effect produced by interweaving fine weft with comparatively coarse warp-ends, which usually work in pairs. Consecutive picks of weft interlace in an opposite manner under and over alternate pairs of warp-ends, which remain perfectly straight, and thereby develop a series of cords.

An example of cord (dyed black, and sold as Bengaline) contains 34 double warp-ends (68 single threads) of 44° yarn, and 96 picks of 44° weft, per inch. Another example (claret coloured, and sold as Biarritz) contains 42 double warp-ends (84 single threads) of 40° yarn, and 200 picks of 60° weft, per inch.

4. *Mistral Voile.*—Voiles are dress fabrics of light open texture for summer wear, constructed on the tabby principle, and piece-dyed in various hues, generally of light and bright tones. When produced in heavier and more open textures they are sold as Canvas. When made up into ladies' garments. fabrics of this class are sometimes lined with cloth of a contrasting colour to that of the voile, with very pretty effect.

An example of voile of medium texture, dyed brown, contains 38 warp-ends and picks per inch, of 2/56° yarn for both warp and weft. Another example, of light texture, dyed pale green, contains 50 warp-ends of 2/120° yarn, and 42 picks of 2/90° weft, per inch.

5. *Estamene* is a name given to a variety of fine serge produced from cross-bred wool, which imparts to the cloth a hard, crisp, and springy texture. They are piece-dyed in various colours,

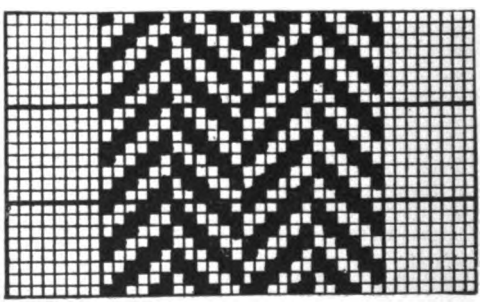

FIG. 1.—(DESIGN A—HERRING-BONE EFFECT.)

but usually in navy and other dark shades of blue, and are based on the four-end ($\frac{2}{2}$) twill weave. A good quality of Estamene contains 60 warp-ends of 2/40° yarn, and 60 picks of 38° weft, per inch.

6. *Chevron* is a trade-name given to a kind of serge fabrics of medium texture, which are piece-dyed in various colours. They are sometimes constructed on the basis of a four-end ($\frac{2}{2}$) twill weave, which is reversed at intervals of several warp-ends to produce the well-known herring-bone effect, as indicated in Design A (Fig. 1). They are also sometimes woven with a chequered or dice effect, by reversing the direction of twill at either regular or irregular intervals of both warp-ends and picks, as

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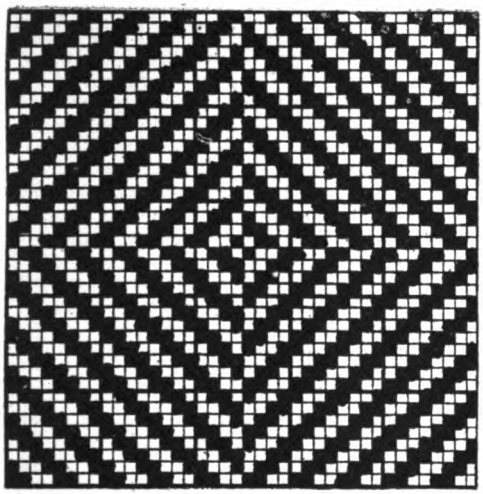

FIG. 2.—(DESIGN B.)

exemplified in Design B. The term Chevron was doubtless suggested by the heraldic bearing of that name; or by the zig-zag moulding known as the chevron, commonly seen in Norman architecture.

An example of chevron cloth of medium texture, produced from Design A, and dyed black, contains 40 warp-ends and picks of 2/28" yarn, per inch. Another example, produced from Design B, and dyed dark green, contains 32 warp-ends of 2/20" yarn, and 28 picks of the same kind of yarn, per inch.

All the foregoing examples have been selected as representative of their particular classes, but they are made in a variety of grades of both superior and inferior quality, and vary in respect of both counts of yarn, and the number of threads per inch. The counts of yarn in all cases are named on the basis of 560 yards per hank.

BALANCE-WHEEL.—Find an expression for the time of vibration of the balance-wheel of a watch, in terms of the moment of inertia of the wheel, together with the dimensions and elasticity of the hair-spring.

The balance-wheel of a watch is in reality a small fly-wheel, accurately balanced about its supporting axle. The hair-spring is a flat spiral spring: the outer end is fixed to the case of the watch in such a manner that the direction of the terminal element of the spring is constant, while the inner end is fixed to the balance-wheel (usually near the centre of the latter) in such a manner that the inner terminal element makes a constant angle with the line joining its point of attachment and the centre of the balance-wheel. The balance-wheel and hair-spring are represented diagrammatically in Fig. 1; in practice the hair-spring would comprise a greater number of convolutions. The hair-spring is hardened and tempered after it has been given the requisite spiral shape. Let the spring in Fig. 1 be in its unstrained position: then it is obvious that on turning the balance-wheel through a small angle in the clockwise direction, the spring will be partially uncoiled, and every element of it will be partially straightened out; on turning the balance-wheel in an anti-clockwise direction, the spring will be more closely coiled up, and the curvature of each element will be increased. The restoring force exerted by the spring on the balance-wheel is thus called into play by the bending of the various elements of the spring, and depends, therefore, on the Young's modulus of the material of which the spring is composed.

The time of vibration of the balance-wheel may be determined by finding the potential energy stored in the spring when the balance-wheel is at the extremity of an oscillation, and equating this to the kinetic energy of the wheel as it moves through its position of equilibrium. At the extremity of an oscillation the balance-wheel is for a moment stationary, and therefore possesses no kinetic energy; as the wheel passes through its position of equilibrium, the spring for an instant regains its unstrained shape, so that at this instant the spring possesses no potential energy: if no energy is lost in over-

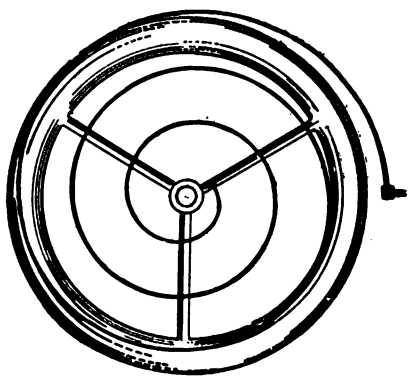

FIG. 1.—(BALANCE-WHEEL.)

coming friction, the total energy of the balance-wheel and spring must remain constant, and therefore the potential energy at the extremity of an oscillation is equal to the kinetic energy as the balance-wheel passes through its position of equilibrium.

We may assume that the angular displacement of the balance-wheel is of the simple harmonic form. Let OA (Fig. 2) represent, to any convenient scale, the maximum angular displacement of the balance-wheel from its position of equilibrium; in other words, OA represents the *amplitude* of the angular vibration of the balance-wheel. With O as centre, and OA as radius, draw the circle ABCD; if we suppose a tracing point P to move round the circle ABCD at a uniform rate, completing its circular path in the time T required for one complete oscillation of the balance-wheel, then at any given instant the angular displacement of the wheel can be found by dropping on OA a perpendicular PX from the position P occupied

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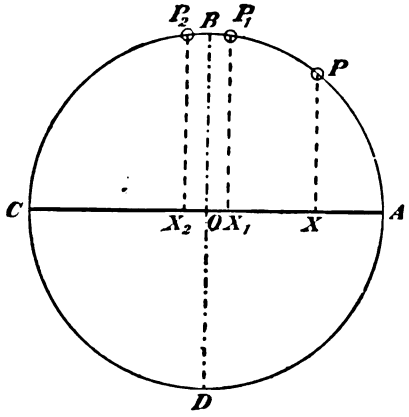

FIG. 2.—BALANCE-WHEEL.

by the tracing point at the instant in question : OX is equal to the angular displacement. As the tracing point passes through B or D, the foot of the perpendicular let fall from it on OA passes through O, so that the displacement vanishes, or the balance-wheel passes through its position of equilibrium. As the tracing point moves from P_1 to P_2, two points near to, but on opposite sides of B, the angular displacement of the wheel changes from OX_1 to OX_2. If P_1 and P_2 are very near to B, the arc P_1BP_2 will be practically equal to the straight line X_1OX_2; and since P_1BP_2 and X_1OX_2 are described in equal times, the *angular velocity of the fly-wheel*, as it passes through its position of equilibrium, is equal to the velocity of the tracing point P, *i.e.*, to $(2\pi\,OA)/T = (2\pi\,\theta)/T$, if OA (the maximum angular displacement of the wheel) is equal to θ, while T is the time of one complete angular vibration. Let I be the moment of inertia of the wheel about its axle ; then if ω is the angular velocity of the wheel at any instant, its kinetic energy will be equal to $\frac{1}{2} I \omega^2$. As the wheel passes through its position of equilibrium, $\omega = (2\pi\,\theta)/T$; hence at this instant its kinetic energy is equal to

$$\tfrac{1}{2} I \left(\frac{2\pi\,\theta}{T}\right)^2$$

We must now determine the potential energy stored in the spring, when the balance-wheel attains its maximum angular displacement θ. We may assume that each element of the spring is bent, but not extended as a whole ; if the cross-sectional area of the spring is rectangular, the neutral surface will be midway between the convex and concave sides of the spring. Let A (Fig. 3) be the point of attachment of the spring, and let AB be part of the spring in its unstrained condition, AB_1 being the same part in its strained condition. Since the spring is not extended, it must be acted on only by a couple at A, due to two equal forces F,F, acting parallel to each other, but in opposite directions, at a definite distance apart. The part AB_1 of the spring must be in equilibrium under the action of the couple at A, together with the restoring couple produced at B_1 by the elongation of the fibres on the convex side, and the compression of the fibres on the concave side of the spring. Draw B_1CD perpendicular to the forces F,F, produced ; then if M represents the restoring couple at B_1, we must have

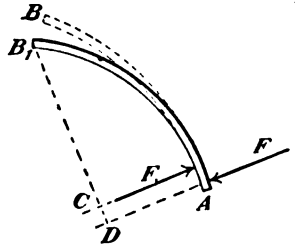

FIG. 3.—(BALANCE-WHEEL.

$$M + F.B_1D - F.B_1C = 0$$
$$M + F.CD = 0$$

Thus the restoring couple at *any* point B_1 on the spring is equal to the couple acting at A ; consequently all cross-sectional areas of the spring will be acted upon by equal restoring couples, and all will be strained similarly. Consequently the potential energy stored in the whole spring, of length l, will be equal to l times that stored in any unit length of the spring.

If opposite forces each equal to f, applied at opposite ends of a fibre of area a and of unit length, produce an extension l, then Young's modulus of the fibre, Y, is given by

$$Y = \frac{f}{a} \div l = \frac{f}{al};$$
$$\therefore f = al\,Y$$

The work done in elongating the fibre is equal to the *average* opposing force $f/2$, multiplied by the distance l through which the force has been overcome. Hence energy stored in the fibre

$$= \tfrac{1}{2} f l = \tfrac{1}{2} Y a l^2.$$

Let Fig. 4 represent unit length of the spring, in its unstrained and strained conditions respectively. In both cases the neutral axis is drawn thus – · – · – ; in the unstrained condition, the end surfaces of the element are inclined at an angle ϕ, while in the strained condition the inclination is equal to ϕ_1. The neutral axis, being unstrained, will remain of unit length ; thus if R and R_1 are the radii of curvature of the neutral axis in the unstrained and strained conditions of the spring respectively, then $R\phi = R_1\phi_1 = 1$. Let Fig. 5 represent the cross-sectional area at either end of the element of the spring ; let AB represent the section of the neutral surface, while the strip CD represents the fibres lying at a mean distance x from AB. The

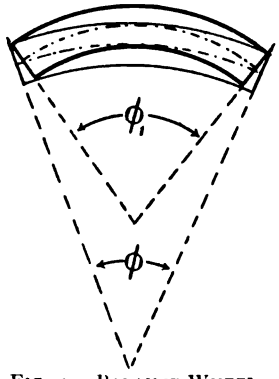

FIG. 4.—BALANCE-WHEEL.

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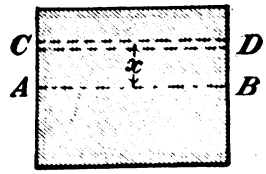

FIG. 5.—(BALANCE-WHEEL.)

original length of the fibres at a distance x beyond the neutral axis was $(R + x)\,\phi$ and their final length, after bending, is $(R_1 + x)\,\phi_1$. Hence the extension l is given by the equation

$$l = (R_1 + x)\,\phi_1 - (R + x)\,\phi\ ;$$
$$\therefore\ l = x\,(\phi_1 - \phi)$$

It is easily seen from Fig. 4 that $(\phi_1 - \phi)$ represents the increase in the angle between the normals to the spring at points unit distance apart, due to bending; since each unit length of the spring is bent to the same extent, in order to produce a constant restoring couple, it follows that L $(\phi_1 - \phi)$ will represent the increase in the angles between the normals at the two ends of the spring, due to bending, L being the length of the spring; *i.e.*, L $(\phi_1 - \phi) = \theta$. Hence

$$l = x\,\frac{\theta}{L}$$

Let a be the area of the strip CD (Fig. 5). Then the energy stored in unit length of the fibres of which CD is a cross-section, will be equal to

$$\tfrac{1}{2}\,Y\,a l^2 = \tfrac{1}{2}\,\frac{Y\theta^2}{L^2}\,a x^2$$

Hence the potential energy per unit length of the spring will be equal to

$$\tfrac{1}{2}\,\frac{Y\theta^2}{L^2}\,\Sigma a x^2$$

where $\Sigma a x^2$ denotes the result obtained by dividing any cross-sectional area of the spring into narrow strips parallel to the section of the neutral surface, multiplying the area of each strip by the square of its distance from the neutral surface, and then adding together the results so obtained. Thus $\Sigma a x^2$ obviously denotes the moment of inertia of the cross-section of the spring, about the section of the neutral surface; let $\Sigma a x^2 = i$. Then energy per unit length of spring

$$= \tfrac{1}{2}\,\frac{iY\theta^2}{L^2}\ ;$$

$\therefore$ Total energy of spring, of length L

$$= \tfrac{1}{2}\,\frac{iY}{L}\,\theta^2.$$

We have now found the kinetic energy of the balance-wheel as it passes through its position of equilibrium, and also the potential energy stored in the spring at the extremity of an angular oscillation of the wheel; equating these, we have

$$\tfrac{1}{2}\,I\left(\frac{2\pi}{T}\right)^2\theta^2 = \tfrac{1}{2}\,\frac{iY}{L}\,\theta^2$$

Since θ cancels out, the time of vibration is independent of the amplitude, so long as the spring is not strained beyond its limits of elasticity. Finally

$$T = 2\pi\sqrt{\frac{I\,L}{i\,Y}}$$

COLOUR SENSE. How is it that a red signal light can be seen more distinctly at a distance than a green one?—*Examination for Factory Inspectors*, 1902.

In the first place, the atmosphere is more transparent to red than to green or blue rays; the shorter the wave-length of the rays, the more they are scattered by small particles of moisture in the air: hence the red colour of the sun when setting. Further than this, the membrane covering the *macula lutea* of the eye is more transparent to red than to other rays of shorter wave-lengths. When a small object is looked at, its image is formed in the middle of the *macula lutea;* if the small object is red (*i.e.*, if it is seen by means of red rays), these rays are scarcely absorbed by the membrane mentioned above; if the rays by means of which the object is seen are of shorter wave-lengths, part of them are absorbed before they can affect the sensitive layer of the eye.

GEOMETRY.—In the plane of a triangle ABC, find a point P such that the sum of the squares on AP, BP and CP shall be a minimum.—(*Taylor's Euclid*, *p.* 166.)

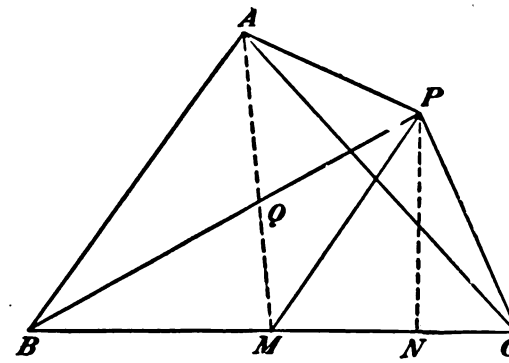

FIG. 1.—(GEOMETRY.)

Let M be the middle point of B C, and P any point in the plane. Join P to A, B, C, and M, and draw P N perpendicular to B C or B C produced. Then, B M P is obtuse or acute, C M P is acute or obtuse, or they are both right angle.

If P M B is obtuse, we get from Euclid (II. 12)

$$PB^2 = PM^2 + BM^2 + 2\,BM.MN.$$

and from Euclid (II. 13).

$$PC^2 = PM^2 + MC^2 - 2\,MC.MN.$$

Hence

$$PB^2 + PC^2 = 2\,PM^2 + 2\,BM^2.$$

It is easily seen that we get the same result in the cases where P M B is acute and when a right angle.

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Hence

$$PA^2 + PB^2 + PC^2 = 2BM^2 + 2PM^2 + PA^2$$

We require then to find the position of P which makes $PA^2 + 2PM^2$ a minimum. Evidently no point outside the median AM can give a minimum, for setting off AQ = AP, along AM, we have MQL < MP and hence

$$2MQ^2 + AQ^2 < 2MP^2 + AP^2$$

By bisecting AB at M_1, we can show in a similar manner that P must be on the median CM_1.

Hence, P must be at the point of intersection of the medians.

(It should be noticed that this gives a proof that the three medians are concurrent.)

SOLID GEOMETRY.—In an isosceles triangle of height h and base $2a$, a circle is inscribed, and in the space left above another circle is inscribed. The whole is rotated about the vertical median. Find the ratio of the surfaces of the spheres thus generated to that of the cone.

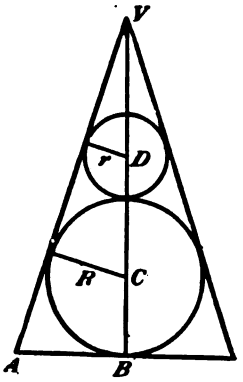

FIG. 1.
(SOLID GEOMETRY.)

Taking for granted that the area of the surface of a sphere of radius r is $4\pi r^2$, and that of the curved surface of a cone is $\frac{1}{2}$ perimeter of base × slant side, the problem resolves itself into finding the radii of the two inscribed circles.

Let VB be the median, and C and D the centres of the two circles of radii R and r. Drop perpendiculars from C and D on the slant side AV.

Then from similar triangles we have

$$\frac{R}{VC} = \frac{AB}{AV}$$

$$\therefore \frac{R}{h - R} = \frac{a}{\sqrt{a^2 + h^2}}$$

$$\therefore \frac{R}{h} = \frac{a}{\sqrt{a^2 + h^2} + a}$$

$$\therefore R = \frac{a}{h}(\sqrt{a^2 + h^2} - a)$$

Again $$\frac{r}{VD} = \frac{a}{\sqrt{a^2 + h^2}}$$

$$\therefore \frac{r}{h - 2R - r} = \frac{a}{\sqrt{a^2 + h^2}}$$

$$\therefore \frac{r}{h - 2R} = \frac{a}{\sqrt{a^2 + h^2} + a}$$

$$\therefore r = \frac{ah}{\sqrt{a^2 + h^2} + a}\left(1 - \frac{2a}{\sqrt{a^2 \times h^2} + a}\right)$$

$$= ah\frac{\sqrt{a^2 + h^2} - a}{(\sqrt{a^2 + h^2} + a)^2} = \frac{a}{h^3}(\sqrt{a^2 + h^2} - a)^3$$

If by the surface of the cone is meant the curved surface plus the base, we have

$$\text{Surface of cone} = \pi a\sqrt{a^2 + h^2} + \pi a^2.$$

Hence $$\frac{\text{Surface of spheres}}{\text{Surface of cone}}$$

$$= 4\frac{\frac{a^2}{h^2}(\sqrt{a^2 + h^2} - a)^2 + \frac{a^2}{h^6}(\sqrt{a^2 + h^2} - a)^6}{a\sqrt{a^2 + h^2} + a^2}$$

$$= 4\left\{\frac{a}{h^4}(\sqrt{a^2 + h^2} - a)^3 + \frac{a}{h^8}(\sqrt{a^2 + h^2} - a)^7\right\}$$

$$= \frac{4a}{h^8}(\sqrt{a^2 + h^2} - a)^3\{h^4 + (\sqrt{a^2 + h^2} - a)^4\}.$$

HYDROMECHANICS.—If the force at any point is given by a potential Φ, and if a tube of small but variable circular section be imagined in the liquid the whole pressure upon which is P, prove that

$$\frac{d^2P}{d\Phi ds} + 2\pi\rho r = 0$$

where r is the radius of the section, and s is measured along the axis of the tube.—(*Besant's Hydromechanics, page* 36.)

By the whole pressure is meant the sum (regardless of direction) of the normal pressures on each of the elements. Thus if p is the pressure at a point, and δs the element of area there, the whole pressure $P = \Sigma p\delta s$, the summation extending over the whole area.

In the case imagined

$$P = \int_0^s 2\pi r p ds + \pi r_1^2 p_1 + \pi r^2 p,$$

r_1 and p_1 being the radius and pressure at the origin end of the tube.

Since r is given as a small quantity, r^2 may be neglected in comparison with r, and hence

$$\frac{dP}{ds} = 2\pi r p$$

and $$\frac{d^2P}{d\Phi ds} = 2\pi r\frac{dp}{d\Phi}.$$

For equilibrium, we know that

$$dp = \rho(X dx + Y dy + Z dz)$$

must be a perfect differential, and since Φ is the potential of the forces

$$\frac{d\Phi}{dx} = -X, \frac{d\Phi}{dy} = -Y, \frac{d\Phi}{dz} = -Z.$$

If, in addition, the fluid is homogeneous, ρ is a constant, and

$$\rho(X dx + Y dy + Z dz) = -d(\rho\Phi) = dp.$$

Hence $$p = -\rho\Phi + a\ constant.$$

and $$\frac{dp}{d\Phi} = -\rho,$$

so that $$\frac{d^2P}{d\Phi ds} = -2\pi\rho r.$$

BOOKS ON THE HIGHER MATHEMATICS.—I have passed the 5th Stage (1st Class) Board of Education Examination in Pure Mathematics, and this year am preparing for the 6th Stage, and the 3rd Stage

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in Theoretical Mechanics. Will you kindly recommend books suitable for work in Higher Mathematics.

Hydrostatics: Greenhill's. (Macmillan, 7*s.* 6*d.*)

Dynamics of a Particle: Tait and Steele's is the standard work, but Besant's Dynamics contains quite enough, and is much less diffuse. At first reading it would be well to omit a good deal of the chapter on "Phoronomy." It is published by Geo. Bell & Sons at 10*s.* 6*d.*

Analytical Statics: The new edition of Todhunter's work on this subject, by Everett. (Macmillan, 10*s.* 6*d.*)

The first volume of Minchin's Statics is also excellent. (Clarendon Press.)

Differential Equations: The standard work is by Forsyth (Macmillan, 14*s.*), and for one seriously studying Higher Mathematics it is indispensable.

A very good work on ordinary Differential Equations is by Page. (Macmillan, 6*s.* 6*d.*)

ELASTICITY.—If a cylindrical wire of length *l*, radius *r*, made of a material whose simple rigidity is μ, has one end fixed, whilst the other end is turned through a small angle ϕ, it can be shown without difficulty that the restoring torque thereby developed is

$$\frac{\mu\phi\pi r^4}{2l} \text{ (approximately).}$$

If the angle ϕ is not small, how can the exact value of the restoring torque be found?

There are several limitations to the generality of the formula, but, that ϕ is necessarily small is *not* one of these. The only limit to ϕ is in connection with the elasticity of the material; if ϕ is so large that the elastic limit to the material has been reached or passed, then the formula is not true. In other words, while the strain is proportional to the stress the formula holds; if ϕ is so large that this is no longer true, in order to find the restoring torque we must know the new law connecting the stress and strain. Such a law (as far as our present knowledge of the constitution of matter extends) must be an experimental one, as indeed is the law, $\frac{\text{strain}}{\text{stress}}$ = a constant.

The difficulty has probably arisen from the way in which the strain is usually measured—*viz.*, by a consideration of the deformation produced in an infinitely small element of the material. In this way it is shown that every point distant r from the axis of the wire undergoes a shear, whose plane is parallel to the axis of the wire, and $\perp$ to the plane through the point and the axis, whose direction is normal to the latter plane, and whose amount is $\frac{\phi r}{l}$. It will be seen that the "very small" refers *not* to ϕ, but to the element of volume considered in finding the measure of the shear.

ELECTRICAL.—Given

$$C = \frac{V}{R + L\theta + \frac{1}{K\theta}}$$

where $V = V_0 \sin nt$ and $\theta = \frac{d}{dt}$, prove that

$$C = \frac{nKV_0}{\sqrt{\{(1 - n^2LK)^2 + n^2R^2K^2\}}} \times \sin\left\{nt + \frac{\pi}{2} - \tan^{-1}\frac{nKR}{1 - n^2LK}\right\}$$

(Kindly give all the steps.)—*Perry's Calculus, p.* 241.

The proof depends on the laws followed by the operator θ. It is defined as obeying the ordinary algebraic law of Indices, and a meaning is then obtained for negative indices. Thus $\theta F(t)$ means differentiate $F(t)$ once, $\theta^3(Ft)$ means differentiate $F(t)$ three times, and $\theta^{-1}F(t)$ means integrate once. Again $(\theta + a)F(t)$ has a definite meaning, and $(\theta + a)^{-1}$ must mean that operation which undoes the operation $(\theta + a)$; similarly $(\theta^2 + a\theta + b)^{-1}$ undoes the effect of the operation $\theta^2 + a\theta + b$ on any function. Hence, if we can see how to undo the operation $(\theta^2 + a\theta + b)F(t)$, we can at once write down what $(\theta^2 + a\theta + b)^{-1}F(t)$ is.

Generally speaking, this is easy when $F(t)$ is a sine function of the time.

$$C = \frac{V}{R + L\theta + \frac{1}{K\theta}} = \frac{K\theta V}{KR\theta + KL\theta^2 + 1}$$

Now $$\theta V = \frac{d}{dt}(V_0 \sin nt).$$

Hence

$$C = \frac{KV_0 n \cos nt}{KR\theta + KL\theta^2 + 1} = \frac{KV_0 n \sin\left(nt + \frac{\pi}{2}\right)}{KR\theta + KL\theta^2 + 1}$$

If, now, we can see how to undo the operation

$$(1 + KR\theta + KL\theta^2)\sin\left(nt + \frac{\pi}{2}\right),$$

we can at once write down the required solution.

Now $$\theta \sin\left(nt + \frac{\pi}{2}\right) = n\cos\left(nt + \frac{\pi}{2}\right)$$

and $$\therefore\ \theta^2 \sin\left(nt + \frac{\pi}{2}\right) = -n^2 \sin\left(nt + \frac{\pi}{2}\right)$$

Hence $$(1 + KR\theta + KL\theta^2)\sin\left(nt + \frac{\pi}{2}\right).$$

$$= \sin\left(nt + \frac{\pi}{2}\right)\{1 - n^2KL\} + nKR\cos\left(nt + \frac{\pi}{2}\right)$$

$$= A\sin\theta + B\cos\theta \quad \text{(say)}$$

$$= \sqrt{A^2 + B^2}\left\{\frac{A}{\sqrt{A^2 + B^2}}\sin\theta + \frac{B}{\sqrt{A^2 + B^2}}\cos\theta\right\}$$

$$= \sqrt{A^2 + B^2}\sin(\theta + a).$$

For an angle a can always be found such that

$$\cos a = \frac{A}{\sqrt{A^2 + B^2}} \text{ and } \sin a = \frac{B}{\sqrt{A^2 + B^2}};$$

and therefore

$$a = \tan^{-1}\frac{B}{A}.$$

Putting in the values of A and B, we see that

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$$(1 + KR\theta + KL\theta^2)\sin\left(nt + \frac{\pi}{2}\right)$$
$$= \sqrt{\{(1 - n^2KL)^2 + n^2K^2R^2\}}$$
$$\times \sin\left(nt + \frac{\pi}{2} + \tan^{-1}\frac{nKR}{1 - n^2KL}\right)$$

The effect of the given operation is therefore to increase the angle by $\tan^{-1}\frac{nKR}{1 - n^2KL}$ and to multiply the sine by $\sqrt{\{(1 - n^2KL)^2 + n^2K^2R^2\}}$ The effect can therefore be undone by dividing by the given quantity and decreasing the angle by the given amount. Hence,

$$C = \frac{nKV_o}{1 + KR\theta + KL\theta^2}\sin\left(nt + \frac{\pi}{2}\right)$$
$$= \frac{nKV_o}{\sqrt{\{(1 - n^2KL)^2 + n^2K^2R^2\}}}$$
$$\times \sin\left(nt + \frac{\pi}{2} - \tan^{-1}\frac{nKR}{1 - n^2KL}\right).$$

The value of C obtained is what is called a "particular solution" of the given equation, and only holds when the current has attained its steady condition, *i.e.*, it is not true just after the current has been switched on.

TWO-PHASE MOTOR.—A two-phase motor is found to take much more power in one phase than in the other. Detail all the causes you know of which may produce this result, and explain fully the tests you would make to determine which of them (if any) is the true cause.—(*City and Guilds Electric Lighting and Power Transmission. Honours*, 1904.)

In searching for the possible causes of one phase of a two-phase motor taking more power than the other phase, it will be convenient to consider the supply circuit and the motor separately. Taking the supply circuit first, and assuming that the motor does not supply the cause, the factors which require consideration are :—

(1) The pressure of the two phases.
(2) The phase relationship between the currents of the two phases.
(3) The wave form of the currents of the two phases.

Under normal conditions the two pressures would be equal, the two currents would be in quadrature with each other, and the wave forms of the two currents would be identical. If the pressures applied at the terminals of the two phases of the motor are not equal, or the two currents are not in quadrature, or the wave forms of the currents are different, the cause of the unequal amounts of power being taken by the two phases may be due to defects in the generation or in the transmission of the power. If faulty construction of the generator be the cause, then all the motors in use on the network will be affected similarly, and the same phase of the supply will in all cases supply (say) more power to all the motors than the other. If difference in wave form be the cause (this can best be determined by means of tests made with an oscillograph), it would appear to be due to defective construction of the generator. It is obvious that if the wave form of the currents of the two phases be different, their form-factors (*i.e.*, the ratios of the virtual values of the currents to their arithmetical mean values) will be different, and this would give rise to a difference in the readings of the two meters.

Then, again, the pressures applied to the terminals of the motor would be different, and the two currents would not be in quadrature with each other, if the impedances of the two circuits were not the same ; for then the drop in the line of one circuit would be different from that of the other. A voltmeter test—using an electrostatic voltmeter—will settle the question as to the equality, or otherwise, of the applied voltage.

Assuming that the supply circuit does not furnish the cause, faulty construction of the motor would give rise to a difference of impedance in the two windings of the motor. Difference between the magnitude of the impedances of the two windings implies either unequal resistances or unequal inductances of the two windings, since the impedances would be different if the two windings were of unequal resistances or of unequal inductances, as would be the case if the number of turns in the windings were not the same. To decide this point, the impedances of the two windings should be compared by sending through each winding separately an alternating current of a given intensity at a given frequency, and noting —by means of an electrostatic voltmeter—the drop in volts across the terminals of each phase. If the readings of the voltmeter be the same for the same value of the current traversing the windings, the impedances of the windings will be equal.

The first test, however, which should be made would be to interchange the connections of the two-phase circuits at the motor terminals, and thus settle whether the cause is in the motor itself or is due to the supply circuit.

The above remarks apply more particularly to the case in which the circuits of the two phases are perfectly independent of each other. Frequently, however, a common or neutral wire is introduced to take the place of the two return mains, and a two-phase, three-wire system is formed. No mention is made, in the above question, as to the kind of system employed. A very interesting case of distortion or disarrangement of the pressures occurs when a common return or neutral wire is employed and the two-phase receiving circuits are inductive, and which is worthy of consideration, as it may probably supply the method of determination as to the true cause of the effect under consideration. Let A and B in Fig. 1 (I) be the two windings of a two-phase motor, which naturally are highly inductive; and let OO_1 be the common return or neutral wire of the two-phase, three-wire system of which 11_1 and 22_1 are the two phase wires respectively. The vectorial diagram of the various pressures

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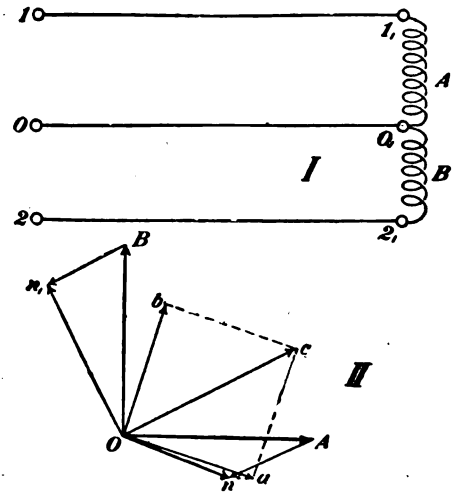

FIG. 1.—(TWO-PHASE MOTOR.)

is given in Fig. 1 (II), in which OA and OB represent the E.M.F.'s supplied to the generator terminals O, 1 and O, 2. Let O*a* and O*b* represent the currents traversing the phase wires 11_1 and 22_1 respectively, then the current traversing the common return wire O_1O will be represented by the resultant vector O*c*. The product of this current into the resistance of the common return gives the drop in pressure in the neutral wire O_1O, which is represented by the vectors A*n* and Bn_1 (Fig. 1 (2)) parallel to the vector O*c*. If we neglect the drop in pressure in the phase wires 11_1 and 22_1, since these have no tendency to distort the two-phase pressures, then the resultant vectors O*n* and On_1 represent respectively the voltages applied to the terminals of the phases A and B of the motor both in magnitude and phase, and it is obvious that the drop in pressure in the neutral wire gives rise to unequal pressures at the terminals of the windings of the motor and a phase-relation between these pressures differing from 90°, which, as previously mentioned, would be sufficient to account for one phase of the motor taking more power than the other.

INSULATION TESTING.—What is the nature of the so-called "electrification" observed when taking insulation tests of cables, and how is this effect allowed for when the formula

$$R = \frac{t_2 - t_1}{2 \cdot 3K \log \frac{D_1}{D_2}}$$

is used for a "Loss of Charge" test?

If the insulation resistance of a cable be determined by the deflection method, the cable is coiled up and immersed in water in a tank, but the two ends of the cable are kept well above the surface of the water. One end of the conductor is connected in series with a delicate galvanometer and a battery, the other end of which is connected to the tank. Upon closing the circuit and making the test, it will be found that the deflection of the galvanometer does not remain constant when the same E.M.F. is continuously applied, but diminishes from instant to instant, as if the insulation resistance increased with time. This diminution is not due to any alteration in the resistance, but to the effects of *electrical absorption* in the dielectric, which may continue for some time. In practice, it is therefore usual to take the deflection after the current has been passing for a definite period of time, generally one minute; this *time of electrification* of the cable, as it is called, being specified along with the resistance.

In the formula used in the *Loss of Charge* test, the electrical absorption is not taken into account, as the formula is derived on the assumption that dielectric resistance strictly obeys Ohm's law.

WAVES.—The waves of the sea, on coming into shallow water, become steeper in front and more gently sloping behind, until at last they curl over on the shore.—(*Maxwell's Theory of Heat.*)
Please explain this fact.

Lord Rayleigh has shown that the water particles of a wave, in addition to their oscillatory motion, are transferred forward in the direction of wave propagation with a velocity decreasing rapidly with the depth. Taking this for granted, we see that as the sea bottom rises to the shore the ratio of depth of water from hollow to bottom to depth from crest to bottom gets less and less, and therefore the retarding force due to the bottom resistance has more and more effect in preventing the translation of the particles in the hollows. In other words, the crest advances more rapidly than the hollow, and the wave ultimately breaks on the shore.

Lord Rayleigh's proof is as follows :—

In the case of deep water, if we attribute to the water a velocity equal and opposite to that of the wave, the wave form, having the same relative velocity as before, is now fixed in space, and the problem becomes one of steady motion. We may therefore suppose the water flowing along a tube whose section is variable (vertically). If then we can show that the time during which a water particle travels from crest to hollow is greater than the corresponding time for a deep particle to traverse the same *horizontal* distance, we have shown that the superficial particles must move in the direction of wave propagation.

Let AB be the surface from crest to hollow and CD a neighbouring stream line, AC being very small.

Let $A_1 B_1$ and $C_1 D_1$ be stream lines at such a depth that the steady motion of the fluid is uniform, the dimension d_1 being such that the

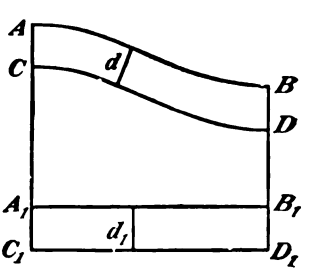

FIG. 1.—(WAVES.)

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same quantity of water flows through d_1 as through any section of the upper tube in the same time.

If then v is the velocity at any point of upper stream line, and v_1 the common velocity in lower,

$$d.v = d_1.v_1 = \text{constant } (k, \text{ say}).$$

The time of motion of a particle from A to B is given by

$$t = \Sigma \frac{s}{v},$$

s being a small distance over which v may be considered constant.

Hence,

$$t = \Sigma \frac{d.s}{k} = \frac{\text{area AD}}{k}.$$

Again, the time a particle takes from A_1 to B_1 is

$$t_1 = \frac{A_1B_1}{v_1} = \frac{\text{area } A_1D_1}{k}$$

Hence,

$$\frac{t}{t_1} = \frac{\text{area AD}}{\text{area } A_1D_1}.$$

Now suppose a number of equi-potential lines (*i.e.*, curves $\perp^r$ to stream lines) drawn in such a manner that the space AD is divided up into a number of little squares, then these same lines will also divide the space A_1D_1 into a number of squares. (Of course, to give squares, CD must be infinitely near AB.)

But if a line is divided into a number of parts the sum of the squares will be least when the parts are equal. Hence the area AD is greater than if the squares described on the parts of AB had been all equal; and therefore *à fortiori*, AD must be greater than A_1D_1, which consists of the sum of the squares of the same number of equal parts of a shorter line.

Hence, of two particles starting at A and A_1 at the same time, the one will arrive at B_1 before the other arrives at B, and there is therefore a motion of translation of the particles in AB relative to A_1B_1 in the direction of wave propagation.

ESTIMATION OF SOAP IN OIL.—Would you please inform me how to detect and approximately estimate soaps, etc., when added to lubricating oils, in order to give more body, but which decompose at high temperatures giving free acids.

On dissolving lubricating oil in benzine, any soap present in the oil will separate out; or again, if a lubricating oil containing soap be shaken with water, a peculiar white emulsion is obtained, which clears on the addition of a mineral acid, as the soap, which is the cause of the emulsion, is immediately decomposed. It is necessary to add the mineral acid, so that an emulsion formed, owing to the presence of soap, shall not be confused with one brought about by some other impurity in the oil.

The presence of soap could also be detected by igniting a portion of the oil in a crucible. The oil burns off, and leaves the metallic base of the soap as a residue. This will usually consist of alumina, as this is the basic constituent most frequently used in preparing soaps for this purpose.

To estimate the amount of the soap, the lubricating oil should be diluted with ether or other suitable solvent, and shaken out with a sufficiency of dilute hydrochloric acid. The soap is decomposed, and the metallic base goes into solution, and is removed with the aqueous layer, and may be quantitatively estimated by the usual methods.

TEXT-BOOKS.—Would you please inform me as to the best and most recent text-books on Theoretical Mechanics, up to the standard of the Board of Education Examination, Stage II, and also Stage III. What is the scope of Cox's Mechanics (Cambridge University Press) and Garnet's Mechanics?

(1) Best and most modern books suitable for Stage II. Theoretical Mechanics (Solids) :—

Briggs and Bryan's Advanced Statics and Dynamics is written specially for this examination. It has, of course, the defects incident to books written for special examinations.

Hicks' Elementary Dynamics is about the best book on the subject, but some students find it difficult to read.

On the whole, Loney's Elements of Statics and Dynamics is perhaps the most suitable, though rather harder than absolutely necessary for the examination. (C. J. Clay and Sons, 7*s.* 6*d.*)

(2) For Stage III., Loney's Elementary Dynamics, in addition to his other work (7*s.* 6*d.*).

(3) Cox's Mechanics (Cambridge University Press, 9*s.*) carries the investigation as far as the elements of the planetary theory, moments of inertia, and the compound pendulum. It is founded on Moch's Mechanik, the questions being treated in historical order, and made thereby interesting.

Garnett's Dynamics (Geo. Bell & Co., 6*s.*) is an excellent work, carrying the student as far as the compound pendulum. There is not a great deal of general theorising; in fact, the bulk of the book consists of examples.

No calculus is used in any of the books so far mentioned.

(4) The first two theorems mentioned under this heading are given in Loney's Elementary Dynamics. The theory of bifilar suspension (though very easy) is not treated in elementary works, and one must go to such works as Love's Theoretical Mechanics, Williamson and Tarleton's Dynamics, or Routh's Rigid Dynamics.

(5) The nearest thing is "An Essay on the Genesis, Contents, and History of Newton's Principia," by W. Rouse Ball (Macmillan, 6*s.*)

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TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

DEAR SIR,—I do not feel satisfied with the solution of the integral

$$\int_0^{\pi} \frac{x \tan x}{\sec x + \cos x}\, dx$$

given in your correspondence column for November; and this for two reasons:—

(1) In dealing with multiple-valued functions the limitations should at each stage be clearly specified.

(2) The value I^1 is obtained by a double change $x = \pi - y$ and $y = \pi - x_1$, the second change following immediately upon the first. To my mind, the same result would have been obtained by making $x = x_1$, which logically leaves us as far forward as ever.

I beg to suggest the following solution:—

$$I = \int_0^{\pi} \frac{x \tan x}{\sec x + \cos x}\, dx$$

$$= \int_0^{\pi} \frac{x \sin x}{1 + \cos^2 x}\, dx$$

$$= -\int_0^{\pi} \frac{x\, d(\cos x)}{1 + \cos^2 x}\, dx$$

$$= -[x \tan^{-1}(\cos x)]_0^{\pi} + \int_0^{\pi} \tan^{-1}(\cos x)\, dx$$

$$= I' + I''.$$

Thus far I agree with your correspondent.

Also, substituting only the limit $x = \pi$

$$I' = -\pi \tan^{-1}(-1);$$

$\tan^{-1}$ is a multiple-valued function, and we must give it a definite range. It repeats its values at intervals π. Let us take the range from

$$-\frac{\pi}{2} \text{ to } +\frac{\pi}{2}.$$

Then $\tan^{-1}(-1)$ can only be $-\frac{\pi}{4}$ and

$$I' = -[x \tan^{-1}(\cos x)]_0^{\pi} = \frac{\pi^2}{4}.$$

Again,

$$I'' = \int_0^{\pi} \tan^{-1}(\cos x)\, dx$$

$$= -\int_{\pi}^{0} \tan^{-1}\{\cos(\pi - y)\}\, dy$$

$$= \int_0^{\pi} dy.\, \tan^{-1}(\cos\pi \cos y - \sin\pi \sin y)$$

$$= \int_0^{\pi} dy \tan^{-1}(-\cos y)$$

$$= \int_0^{\pi} dx \tan^{-1}(-\cos x);$$

since it is of no importance whether we give the name x or y to the variable in a functional form varying between definite limits. It is the *functional form* alone that matters.

Hence

$$I'' = \int_0^{\pi} dx \tan^{-1}(\cos x)$$

$$= \int_0^{\pi} dx \tan^{-1}(-\cos x).$$

Now $\tan^{-1}$ has been allotted the range

$$-\frac{\pi}{2} \text{ to } +\frac{\pi}{2}.$$

Within this range,

$$\tan^{-1} A = -[\tan^{-1}(-A)];$$

$$\therefore 2I'' = \int_0^{\pi} dx [\tan^{-1}(\cos x) + \tan^{-1}(-\cos x)]$$

$$= \int_0^{\pi} dx\, (0) = 0$$

Hence $I = \frac{\pi^2}{4}$.

Had we given $\tan^{-1}$ the range $0 - \pi$, the sign of the result would have been changed. I imagine that the logical circle in the latter part of Mr. Child's reasoning is due to the suppression of some essential element in the proof rather than to any error of a purely mathematical kind. Still, in the interests of lucidity I offer my suggestions for what they are worth.

I am, Sir,
Yours faithfully,
G. GUTHRIE ROGER.

To the Editor of TECHNICS.

DEAR SIR,—With reference to the article on tricolour-photography in your November issue, I should like to point out that Mr. Bennett has fallen into the error, which is very common with writers on this subject, of using the "colour mixture" and "colour sensation" curves indiscriminately.

In the text of the article he refers to the Clerk-Maxwell *colour mixture* curves, and then goes on to state that Sir W. Abney's *sensation curves* are a redetermination of these, giving a diagram of the sensation curves.

This error was, I think, first pointed out by Mr. A. J. Bull and myself in a paper on Tricolour Filters read before the Optical Society of London, in which the following definitions will be found:—

Maxwell's *colour mixture* curves are those which are obtained by matching each part of the spectrum by three monochromatic lights.

The *sensation* curves are those which give for every point of the spectrum the relative amounts of the three sensations which are stimulated in

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the eye, and which together make up the visual effect produced. From these definitions it can be seen that there is a distinct difference between the two sets of curves. We have further shown that filters which attempt to follow either mixture or sensation curves do not give the best results in practice, and that it is preferable to have abrupt absorptions and definite regions of overlap if the best results are desired.

Mr. Bennett further states that the printing colours should be complementary to *the sensations*. Now, as far as I can see, these have no physical existence; since the printing colours will each cause a partial stimulus of two or more of the fundamental sensations, not necessarily of fixed amount.

With regard to the use of one type of plate for all exposures advocated in the article, all that is required is that the scale of gradation shall be equally rendered in all three negatives; now many of the so-called panchromatic plates will not do this, and one is therefore obliged to use dissimilar plates. The Bolt Court school and many commercial firms are doing this.

There are many minor points, both practical and theoretical, which are debatable in the article, but I will not trespass further on your space to discuss them here. But one cannot pass without remark the exposure ratios given by Mr. Bennett.

I give below the ratios of three sets of filters taken at random, which are fairly representative of ordinary practice :—

	Blue.	Green.	Red.
L. N. A. Co. . . .	1	6	14
F. E. Ives	1	8	12
Rotary Photo. Co. .	1	2	12

In no case is the blue exposure more than four times the normal exposure.

Yours faithfully,

A. C. JOLLEY.

To the Editor of TECHNICS.

SIR,—With your permission I would like to reply to Mr. DeBarry Barnett.

Mr. DeBarry Barnett states that the idea in the construction of the Great Pyramid was to make the square of the height equal to the area of one of its triangular faces, and that the π proportion between the height and twice the length of base was merely a coincidence. If this theory be correct it gives the Pyramid designers credit of knowing another truth than a correct method of calculating the value of π, *viz.*, Euc. I: 47; this theorem, however, is credited to Pythagoras, who was centuries after the Pyramid. However, in this I agree, that the designers knew I : 47 before Pythagoras, as also did the Hindoos; the calculation of π was simply an extension.

Now to proceed, Mr. DeBarry Barnett simply gives the late Mr. Taylor's interpretation of Herodotus; but Herodotus only had a sort of traditional account, and therefore absolute reliance cannot be placed upon his writings, and we must therefore fall back upon the work of modern investigators; and of these Colonel Howard Vyse appears to me to stand pre-eminent. The Colonel, at great expense and labour, had one side of the base of the Pyramid absolutely cleared of all débris—the accumulation of centuries—for the purpose of measuring the original length of the base, and fortunately during this work came across two of the original casing stones *in situ*. These stones, about 5 ft. × 8 ft. × 12 ft., were finished with practically mathematical accuracy. The Colonel, with his assistants, then measured with all the accuracy possible in the circumstances, the angle of the inclined face, the mean of all the trials giving 51°. 51′. 14″. The sine of this angle is therefore the height, and the cosine, half the base of a relative pyramid. On working this out it will be found that,

$$\sin\phi : 4\cos\phi :: 1 : \pi \text{ (very nearly)}$$

$$\begin{aligned} \text{L}\cos\phi &= 9{\cdot}79077 \\ \log 4 &= \ {\cdot}60206 \\ & \overline{10{\cdot}39283} \\ \text{L}\sin\phi &= 9{\cdot}89565 \\ & \overline{{\cdot}49718 = \log\pi} \end{aligned}$$

Now at present I have only five figure logs by me, but I remember that the log of π, to a fairly high standard of accuracy, is ·4971499. It therefore appears to me clear that the coincidence is, that the square of the height is practically equal to the area of a triangular face, rather than that the π proportion is a coincidence.

When I wrote my original letter, I did not anticipate this developing into a Pyramid discussion, but there is one other point, out of a number that could be raised, I would like to ask Mr. DeBarry Barnett. The Great Pyramid is situated practically on the 30° of latitude, and therefore had the earth been a perfect sphere, it would have divided the northern hemisphere into two equal areas, *i.e.*, the area of the band around the earth between the latitude of the Pyramid and the equator would be equal to the whole area above the latitude of the Pyramid. I say "practically on the 30° . . ." because it is not quite there—a trifle below it in actual fact, as if to indicate that the designer knew perfectly well that the earth was not a sphere, and that the flattening at the poles, and more slightly at other places, reduced the area from what it would have been had the earth been perfectly spherical. Is this a coincidence also? I most certainly do not think so. How these early builders obtained their knowledge I do not pretend to say; it appears to me, however, that that early race had absolute and definite information of certain scientific facts that have only, comparatively, been recently rediscovered.

Yours faithfully,

F. BROWN, Capt. A.O.D., Wh.Sc.

To the Editor of TECHNICS.

DEAR SIR,—May I thank your correspondent, Mr. E. Holden, for pointing out two obvious oversights in my article* on "Dampness in Houses."

*TECHNICS, Vol. I., No. 10, October, 1904, pp. 382-385.

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In Fig. 8 I inadvertently showed the bonding bricks laid as if the thicker wall were the outer one, as it is sometimes, but I did not intend it to be so in this case. Also in Fig. 11 the window nosing is shown fixed to the brickwork instead of to the window-sill, as every building construction student knows it should be.

I am extremely sorry that the mistakes were not discovered by me in correcting the proof.

The corrected drawings for Figs. 8 and 11 are appended herewith.

Yours truly,

RUFUS E. MARSDEN.

22, Howson Road,
Brockley.

Nov. 28th, 1904.

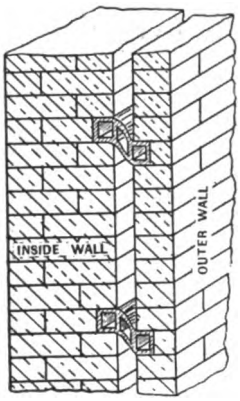

FIG. 8.

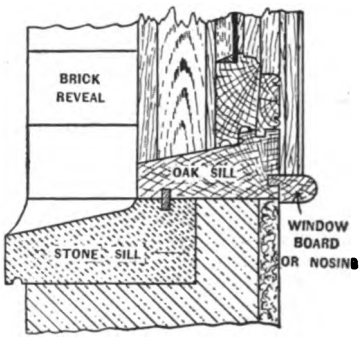

FIG. 11.

"TECHNICS" COMPETITIONS.

IN the first twelve numbers of TECHNICS, competitions have been set from month to month on subjects ranging over the greater number of technical industries. Very excellent work has been sent in by many of the competitors, but the total number of competitors has proved much smaller than we expected, with the result that, as a regular feature of TECHNICS, the competitions will be discontinued in future. We shall endeavour to publish the results of the November and December competitions, if possible, in the February number. As soon as a comparison between the work of the various competitors throughout the year can be completed, the name of the TECHNICS Prizeman will be announced, and a cheque for £200 and a gold medal will be forwarded to him.

RESULTS OF OCTOBER COMPETITIONS.

CHEMISTRY.

PRIZE, £3.—Bertie J. Eaton, 37, Belitha Villas, Barnsbury Park, London, N.

SPECIAL HONOURABLE MENTION:—R. T. G. French; E. H. Higgins; R. Lessing; Harry Hutchinson.

HONOURABLE MENTION:—Harold Slicer; Geo. J. Denbeigh; Earby Dalton.

ENGINEERING.

PRIZE, £3.—H. E. Hodgson, South-Western Polytechnic, Chelsea, S.W.

SPECIAL HONOURABLE MENTION:—Frank H. Eldershaw; H. C. Young; A. Richards; Lionel E. Macklin; H. G. Lester; T. M. Barlow; F. L. Berry; Percy Warwick.

HONOURABLE MENTION:—W. J. Richards; H. H. Roberts; H. A. Stewart; Harold Slicer, C. Ernest Holloway; S. Irwin Crookes; J. M. Young; Arthur Gadd; John Ramsay.

ELECTRICAL ENGINEERING.

PRIZE £3.—Harold H. Broughton, 69, Edburton Avenue, Brighton.

SPECIAL HONOURABLE MENTION:—Charles Ernest Savage; A. J. Aldridge.

HONOURABLE MENTION:—P. E. Banting; Albert Beeston; Archibald Bursill; H. A. Stewart; H. E. Hodgson.

COTTON SPINNING.

PRIZE £3.—John E. Tytler, 13, Hartley Street, Henderson Street, Levenshulme, Manchester.

SPECIAL HONOURABLE MENTION:—Edward Runcorn; A. W. Brierley; Herbert Wroe.

HONOURABLE MENTION:—Robert Marcroft; Frederick Stones; Harold Andrew.

EXPANSION CURVES.

FIRST PRIZE, £1 10s.—H. J. Trust, 31, Grove End Road, London, N.W.

SECOND PRIZE, £1.—R. Proudlove, 32, Hutt Street, Spring Bank, Hull.

THIRD PRIZE, 10s.—Samuel Lees, 1, Trafalgar Street, Broughton, Manchester.

SPECIAL HONOURABLE MENTION:—Jessie Haigh Baxter; R. W. Blair; J. H. Magson; Edwin Magson; Harold Slicer; C. B. Hurst; Ernest W. Sanders; S. Irwin Crookes; H. E. Hodgson.

HONOURABLE MENTION:—W. E. Dommett; D. Fulton; A. Richards.

ELECTRO-MAGNETIC THEORY.

PRIZE, £5.—Divided equally between two competitors: H. G. Trust, 31, Grove End Road, N.W.; and A. Richards, Deira, Drummond Terrace, Crieff.

SPECIAL HONOURABLE MENTION:—C. H. Finnis; Edgar P. Hedley; Oswald J. Harding; J. K. Wilkins; J. Boswell Wilton; H. H. Francis Hyndman.

HONOURABLE MENTION:—Arthur H. Bird; Geo. J. Denbigh; William J. Williams; H. A. Stewart; G. Oliver Campbell; Charles Percy Hines; S. Irwin Crookes, Samuel Lees.

THEORY OF STRUCTURAL DESIGN.

PRIZE, £5.—D. E. Synan, 36, Cecil Street, Limerick.

SPECIAL HONOURABLE MENTION:—Samuel Lees; K. Bonallo.

HONOURABLE MENTION:—W. Jno. Richards; Arthur Gadd; H. Stringer; Harold Slicer.

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PERSONAL ITEMS.

WE have received from Messrs. F. E. Becke & Co. an illustrated and descriptive catalogue of Physical Apparatus and Appliances. This catalogue is quite unique as regards completeness, and should be in the hands of everyone whose duties involve instruction in the use of physical apparatus; mathematical drawing instruments, slide rules, callipers, and other instruments of precision are included, as well as apparatus for practically every experiment commonly performed in the physical or chemical laboratory. The catalogue is profusely illustrated throughout.

THE December number of the *Irish Technical Journal* contains an interesting article on the central battery system of telephone working, as well as other instructive matter; in a description of the recent Arts and Crafts Exhibition, it is stated that this was the best of its kind ever held in Ireland.

PROFESSOR H. S. HELE-SHAW, LL.D., F.R.S., has resigned the Chair of Engineering in the University of Liverpool, in order to take up the duties of Principal of the Transvaal Technical Institute and Organiser of Technical Education in the Transvaal, to which position he has been appointed for twelve months. Last year, upon the invitation of the Colonial Secretary, Professor Hele-Shaw went out to the Transvaal as Organiser of Technical Education. On arrival, he accepted the position of senior and responsible professor of the new technical institution, which he duly opened, with, besides himself, five assistant professors in engineering, geology, mining, chemistry, and physics and electrotechnics. Forty-three students, both Dutch and English, who were taking the examinations of the Cape University in mining, presented themselves. In addition, evening classes were opened at Pretoria, Johannesburg, and other places on the Rand, and were attended by several hundred students. On December 6th, Professor and Mrs. Hele-Shaw attended an At Home at the Walker Engineering Laboratories, Brownlow Hill. During the evening the Professor delivered an interesting lecture on the problem to be faced in connection with the industrial progress of the Transvaal. In connection with the subject of Chinese labour, he said that at the present moment some 25,000 Chinese were at work in the Rand, and that their advent had led to the immediate occupation of several thousand white men who had previously been out of work.

AT the January meeting of the Society of Dyers and Colorists, Mr. F. T. Farrell, M.Sc., will read a paper on "Production of Crepon Effects on Silk Fabric by Chemical Means," and Mr. Fredk. Hewitt will read a paper on "The Dyer: his Trade and Position." Particulars may be obtained from the Honorary Secretary, Mr. M. Charles Lamb, F.C.S., of 151, Westcombe Hill, Blackheath, London, S.E.

THE North-East Coast Institution of Engineers and Shipbuilders will hold the fourth meeting of the session at Newcastle-on-Tyne, on Friday, January 20th, 1905, when a paper on "Petrol Motor Cars" will be read by Mr. F. Little, A.M.I.E.E.

MR. R. C. CLINKER, of Rugby, has kindly drawn attention to an error made by the inventor in the explanation of his magnetic speed indicator, which was described and illustrated in the September number of TECHNICS (Progress of Science and Technology, p. 213), the same error being fallen into by our contributor in abstracting the information from the patent specification. Mr. Clinker points out that the torque is produced by the currents induced in the copper or aluminium disc between the poles of the magnets, and that this torque is proportional to the speed, hence the evenly divided scale.

AT the St. Louis Exposition the Westinghouse Companies received gold medals as follows:— For complete A.C. and D.C. switchboards, Bremer arc lamps and arc lighting system, Nernst lamps, Cooper-Hewitt lamps for photo engraving, water and gas meters, electric measuring instruments, and for industrial betterment work and housing of the working class. The Westinghouse Companies have come out top in the list of prize-winners, having received the largest number of awards ever bestowed upon a single firm at any World's Fair.

MESSRS. A. & C. BLACK have published the 1905 issues of three useful works of reference: "Who's Who," "Who's Who Year Book," and the "Englishwoman's Year Book." This year, "Who's Who" has once more been enlarged; nearly 100 pages have been added, bringing the total up to 1796 pages. Men distinguished for their scientific and technical abilities, both in this and foreign countries, come in for a due share of notice.

ON December 1st, Sir William White, K.C.B., distributed the prizes and certificates gained by students of the Sir John Cass Technical Institute during the session 1903-4. The chair was taken by Sir Owen Roberts, Chairman of the Governing Body. In the course of his address, Sir William White said that during his recent visit to America he had taken the opportunity to study the educational systems in vogue there, and he was obliged to confess that both the United States and Canada can teach us much with regard to technical education. A noteworthy feature in these countries is the interest taken by employers of labour in educational work, as well as in the employment of men who have received adequate technical and scientific training.

THE Registrar of the University of Leeds announced, at a Mansion House meeting held at York, on November 30th, in support of the University, that £61,825 has been subscribed towards the £100,000 required to make the necessary additions to the buildings and to increase the endowment of the University, so as to satisfy the financial requirements laid down by the Committee of the Privy Council.

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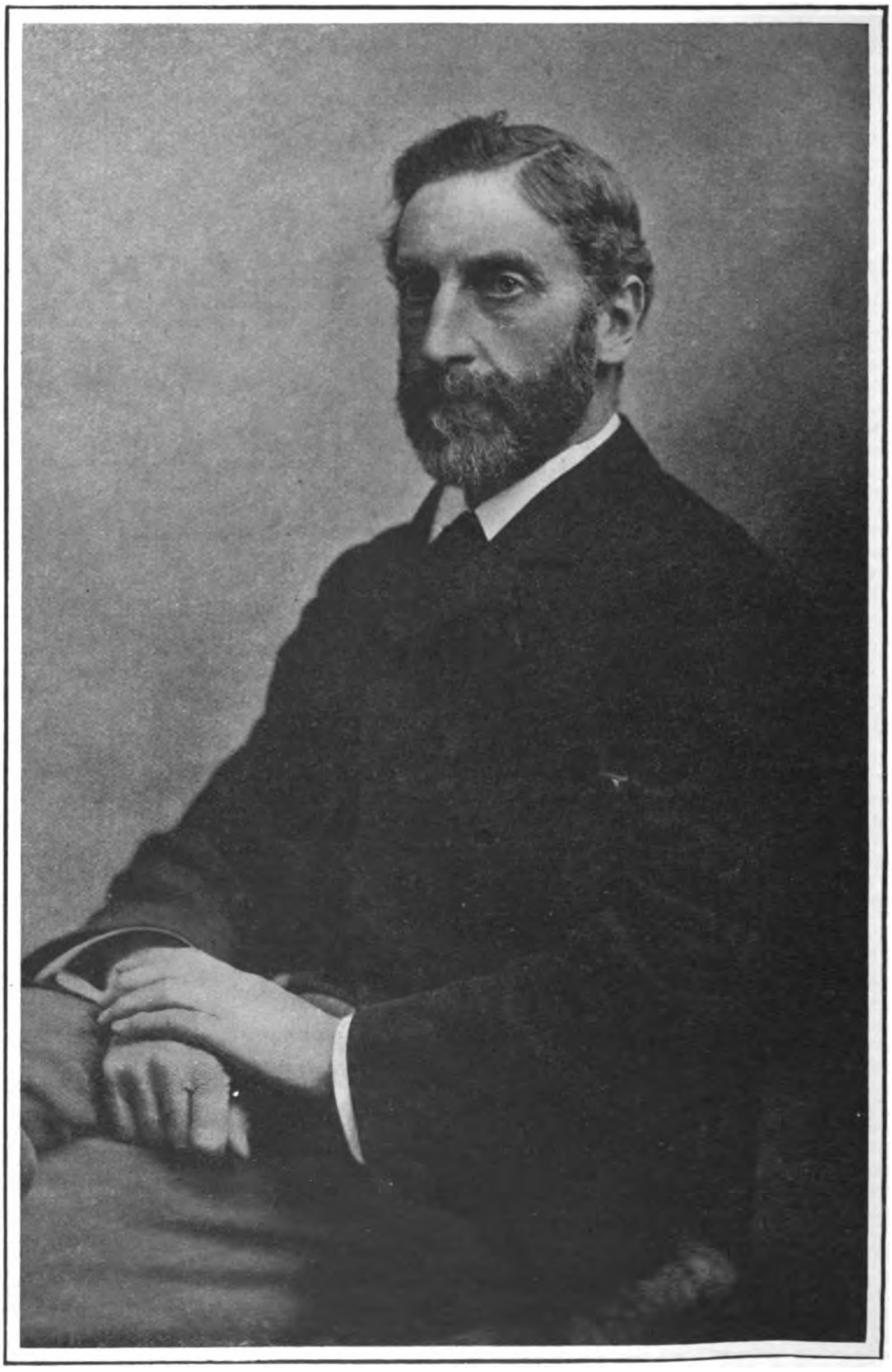

Dr. JOHN HOPKINSON.

Born July 27th, 1849. *Killed in an Alpine accident, August 12th*, 1898.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. III. FEBRUARY, 1905. No. 14.

PROGRESS OF SCIENCE AND TECHNOLOGY.

CONSIDERING the mental labour which must necessarily be gone through before the distinction of Senior Wrangler and Smith's Prizeman can be obtained, it is somewhat surprising that the subsequent careers of Senior Wranglers are not more usually of a brilliant and noted character. There are comparatively few who have gained the above distinction, and have afterwards attained eminence in the scientific or technical world: one of the most notable exceptions was the late Dr. John Hopkinson. Born at Manchester on July 27, 1849, John Hopkinson proceeded to Cambridge at an early age, and became Senior Wrangler and Smith's Prizeman in due course. Though elected to a fellowship, he preferred the work of a consulting engineer, and for some time was associated with the firm of Messrs. Chance, manufacturers of optical glass. Coming to London, he soon gained a large consulting practice, and for some years filled the chair of electrical engineering at King's College. While yet a student at Cambridge, Dr. Hopkinson invented the three-wire system of electrical distribution. Previous to the researches of Dr. John Hopkinson and his brother relative to the magnetic circuit, the successful design of a dynamo was very much a matter of chance; if the voltage of the completed machine came out within twenty per cent. of the required value, the design was considered satisfactory—or at least, as satisfactory as could be expected. Now-a-days an electrical engineer can design the magnetic circuit of a dynamo so as to obtain a voltage within three or four per cent. of that required: indeed, a closer agreement would be possible were it not for the difficulty of correctly estimating the permeability of the iron or steel used in constructing the magnet poles, cores, and yoke. This success is mostly due to the labours of the brothers Hopkinson; although the applications of the principles deduced by these investigators are so simple and straightforward that many engineers apply them without having understood the grounds on which they are based, yet it was a notable stroke of genius to apply these principles in the first case. Although an eminent mathematician, Dr. Hopkinson possessed that sense of proportion, denied to many possessing mathematical attainments, which is necessary where mathematical analysis is to be applied to the problems presenting themselves in the workshop; hence his noted graphical solution of the problem of the magnetic circuit of the dynamo, which others had vainly sought to solve by the aid of ordinary analytical methods. The career of this eminent investigator was cut short in a terrible manner: Dr. Hopkinson was a celebrated mountaineer, and while climbing the Petite Dent de Veisivi, above Evolena, on August 12th, 1898, he, and a son and two daughters, were killed in an accident of which the details are unknown.

Dr. John Hopkinson

IN dry weather the fibres used in the textile industries are liable to become electrified during combing and other similar operations, with the result that their treatment becomes very difficult. It is now well known that the discharge of α-rays from a radio-active substance "ionises" the air in its neighbourhood (that is, renders this air a conductor of electricity), so that an electrified body placed near a radio-active substance is quickly dis-

Radio-activity and the Textile Industries

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charged. This property might perhaps be utilised in the textile industries to prevent the electrification of the fibres. The cost of radium is so great that this substance could scarcely be used; but thorium (which is much cheaper) has similar properties, although its ionising capacity is smaller: even disused gas mantles will quickly discharge an electroscope in their neighbourhood. We should be pleased to hear of the results of experiments in this connection, which could be readily carried out by anyone engaged in the preliminary operations of the textile industry.

The Present Position of X Rays in Medicine and Surgery.

THE address delivered to the Röntgen Society by the President, Dr. C. Thurstan Holland, on November 3rd, 1904, gives an admirable account of the medical and surgical uses of X rays. For a few years after Röntgen's discovery, medical men were divided in opinion as to the benefits to be derived from the use of X rays; some held exaggerated ideas of these benefits, whilst others went to the opposite extreme, and greatly underrated them. At the present time, the uses to which X rays can be put by a competent surgeon are fairly well defined. In the first place, it is known that the opacity of an object to X rays depends merely on its density; consequently, reports of the detection, by the aid of X rays, of diamonds swallowed by thieves, are purely mythical. On the other hand, a needle embedded in the hand can be exactly located, and removed in less than five minutes; and although Mr. Brodrick, in 1898, informed the House of Commons that, in the Egyptian campaign, no single case had occurred in which X rays could have been usefully employed, it is certain that the greatest benefits could have been derived from their use. It is now safe to say that in no circumstances is a surgeon justified in operating for the supposed presence of a foreign body unless he has first proved its presence, and located its position, by the aid of X rays. All bone injuries ought to be examined by the aid of X rays, both before and after an operation. In the case of some bone diseases, such as central abscess of the bone, X rays furnish practically the only guide to the surgeon. It is now possible to detect with certainty the presence of renal calculi; but in this case it appears to be necessary to take radiographs by long exposure, and also by short exposure while the patient holds his breath: in some cases where a long exposure has produced a negative showing no sign of a solid body, this has been due to movement of the kidneys during respiration, and a short exposure has revealed the presence of a stone. The exploratory operation of cutting down on a kidney for "suspected" stone ought now to be almost, if not quite, obsolete. The diagnosis of stone in the bladder is quite simple, and should admit of no mistake being made.

Application to Chest Diseases

X RAYS have proved valuable in the examination of patients suffering from diseases of the chest. "It is scarcely going too far" (to quote from Dr. Holland) "to say that the only certain means of diagnosing thoracic aneurism is a careful X-ray examination, and that the skilled radiographer can nearly always answer 'yes' or 'no' if the question for or against is put to him. Next to aneurism, the great value of X rays is seen in cases of pulmonary consumption. In the first place, a careful examination of an affected chest at intervals, during the course of an illness, may not only be of great interest, but also of great use, as an additional means of indicating the course of the disease; and in the second place, in the very early cases—the merely suspicious cases, indeed—an X-ray examination is essential. It has been proved beyond all doubt that marked radiographic changes from normal, suggestive of tubercular disease, have now been found when only the merest suspicion of phthisis has existed; when no so-called physical signs have been detected; when no tubercle bacilli have been found in the sputum, if there was any of the latter to be obtained; when the only symptoms giving rise to anxiety have been some ill-health, loss of weight, and perhaps cough and dyspeptic troubles. It is a serious matter to urge, say, a business man, with much depending upon him, to throw up everything and go through several months of open-air treatment on a vague suspicion alone; it is still more serious to put off doing this until unequivocal signs have developed, and it may be too late. Radiography, in these cases, is now invaluable; and it is not going too far to assert that in such a case, given a radiographic examination by one competent to form an opinion—a most important matter—if suggestive radiographic changes are found, the patient can be unhesitatingly advised of his danger and the necessity of immediate action; given no radiographic changes, it is quite justifiable to wait and watch.

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"The most important early radiographic changes are those seen on the screen: firstly, some restriction of the diaphragmatic movements on the affected side; secondly, some difference in the transluceing of the normal lung tissues to the X rays. This latter may be detected by either screen or plate."

X Rays and Skin Diseases

MANY skin diseases have yielded to treatment with the X rays. To once more quote from Dr. Holland's address:—"In large numbers of skin diseases—acne, favus, ring-worm, sycosis, eczema, psoriasis, and others (I do not intend this to be a complete list) X rays have proved useful. They have also been used for the removal of superfluous hairs, for the treatment of trachoma, and so on. But the three diseases which are the most interesting from this point of view are lupus, rodent ulcer, and malignant disease other than rodent ulcer . . . . . In 1898 I had the pleasure of recording the first successful case of the treatment of lupus by X rays in this country, and the patient at the present time, except for two slight relapses rapidly cured, remains well . . . . In the treatment of lupus generally, my opinion is in favour of the X rays as against the Finsen light or any of its modifications. This means, I take it, that in my hands the treatment by X rays has appeared to me to give better results. Certain advantages are obvious: X rays are easier of application and more comfortable to the patient; the treatment, as a rule, extends over a shorter time; the whole area can be treated at each sitting; X rays can reach a part where it is difficult or impossible to apply the Finsen treatment. As against these advantages one may say there is the risk of an X ray burn; but I would put this entirely on one side, providing that proper care is used. Like all treatments, X rays are not infallible, but I have never yet seen methodical and properly carried out X ray treatment fail to produce a favourable effect in any case of lupus. In rodent ulcer, as we all know, the effect of X rays is marvellous. The only question that has to be decided is that between X rays and operation. This does not come in when the case has gone too far for the surgeon's knife, but the remarkable success of X rays, even in these cases, compels one strongly to the idea that when we understand better the technique of X ray application, this treatment may take the place of the knife in all cases.

Malignant Growths

"THE position of X ray treatment in true malignant disease, sarcoma and carcinoma, is very difficult to sum up. The cases which usually present themselves for treatment are either primary growths of an inoperable character, or else inoperable recurrences after operation. Often X rays do nothing—do not even relieve the pain—and, indeed, there is the suggestion that they may sometimes hasten the course of the growth, and hurry on secondary and general infection . . . . Most of us who have worked in this direction have seen the most extraordinary results occur: large areas of disease absolutely disappear; ulcerations heal up; the general health of the sufferer markedly improves; everything points hopefully to a successful result. Then a gland is noticed to be enlarging, then another, deposits of new growth occur elsewhere, and the case becomes hopeless to any kind of treatment known at present."

Dangers of X Rays

ALTHOUGH manifest benefits have been derived from the use of X rays, yet their use is not without some element of danger:—"The most recent case of this kind is one that has occurred in America. Dr. Weigel, of Rochester City, United States, one of the most skilful and enthusiastic of American surgeons who used X rays, was in England one year ago. He was then suffering very badly from chronic dermatitis of the hands. A short time ago cancer supervened, and on October 11th it was found necessary to amputate the right hand at the wrist, and to remove the first, second, and third fingers, and a portion of the metacarpus of the left hand. One may expose one's hands to the rays with impunity for years, but the risk is great, and I have no doubt that the effect of these constant exposures is, so to speak, cumulative, and that, as time goes on, the hands get more and more "tender" to the rays. It matters not very much whether the effects produced are caused by the X rays themselves, or some other agent; whatever it is, an active X ray tube is a danger to the operator, and one cannot be too careful in guarding oneself against this danger. At the same time, certain articles in the daily press are calculated to do harm, as many of the general public reading them may be led to conclude that there is danger of chronic dermatitis and cancer being caused by having an X ray examination made, or by being treated with X rays. Some people, on this account, may be led to refuse either to

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be examined or treated by the rays when either the one or the other may be necessary. It may be definitely stated that no harm whatever can follow a properly conducted X ray examination, and I think one is also justified in saying that the treatment by X rays in skilled hands is also harmless."

Allotropic Modifications of Iron

It is well known that if a molten substance is allowed to cool slowly, and its temperature is continuously observed, the latter will remain constant while solidification is occurring, after which the temperature falls till the substance becomes as cold as its surroundings. Now, the rate at which the substance loses heat depends merely on the dimensions of the vessel containing the substance, and the difference between the temperature of the substance and its surroundings; hence, if the temperature remains constant while the substance is hotter than its surroundings, we know that the substance is losing heat at a constant rate, and we must infer that it is somehow gaining as much heat as it loses. So far as the phenomena attending solidification are concerned, the gain of heat is easily explained: as the substance solidifies, its latent heat of liquefaction is given up, and this keeps the temperature of the substance constant until solidification is complete. By the aid of a Le Chatelier pyrometer, a cooling curve for iron can be obtained, starting with the molten metal, and ending with the solid metal at the ordinary temperature of the room; such a cooling curve presents many interesting features. The fall of temperature is temporarily arrested at about 1,530° (Fig. 1) corresponding to the process of solidification. There are also three other points in the curve

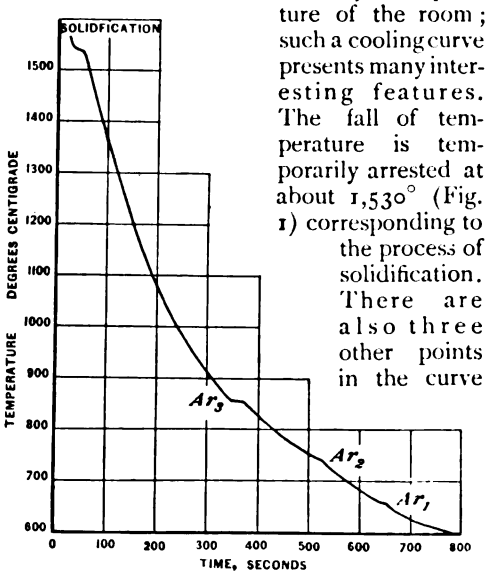

FIG. 1.—COOLING CURVE FOR PURE IRON.

which denote temporary arrests in the fall of temperature; these are denoted by Ar_3, Ar_2 and Ar_1; for pure iron these arrest points occur at 860°C., 750°C., and 660°C. Each of these arrests in the fall of temperature denotes an evolution of heat; and since the points Ar_3 and Ar_2 are perfectly distinct in the purest electrolytic iron procurable, the conclusion has been arrived at by M. Floris Osmond and his followers that Ar_3 and Ar_2 denote allotropic transformations. Above Ar_3 iron is assumed to exist as γ ferrite; at Ar_3 a transformation to β ferrite occurs, while at Ar_2 a transformation to α ferrite occurs. The arrest point Ar_1 is scarcely noticeable with the purest iron procurable, but it becomes very distinct in high carbon steels; hence, we may conclude that Ar_1 does not correspond to an allotropic transformation. If a steel knitting-needle is heated to a bright red heat, and is then watched as it cools in a dark room, the luminosity of the needle will be observed to vanish, then to reappear, and finally to die away. The reappearance of the luminosity is due to the evolution of heat at Ar_1; this phenomenon is called *recalescence*.

It is certain that an evolution of heat occurs at Ar_3 and at Ar_2, and it is probable that the same phenomenon would occur if perfectly pure iron could be procured; hence, we are justified in assuming that Ar_3 and Ar_2 denote allotropic transformations. Professor H. M. Howe has proposed the following definition:—"Allotropy is a change in the properties of an element without change of state. It is habitually accompanied by a change of internal energy. It is due in some, and perhaps in all cases, to a change in the number or the arrangement of the atoms in the molecule." α, β and γ ferrite have properties which clearly distinguish them from each other. α ferrite is ordinary pure wrought iron; it possesses a high magnetic permeability, and a relatively small coefficient of thermal expansion. If α ferrite is heated, it changes to β ferrite at the point Ar_2 (750°C.); the permeability of iron increases with the temperature till the point Ar_2 is reached, when it abruptly falls to the value unity, which leads us to conclude that the molecular structure of β ferrite is such that it is non-magnetic. Further, the rate of increase of electrical resistance with the temperature is much greater for β than for α ferrite; hence, if the volts across a piece of iron wire are observed as the iron is heated up with an increasing electric current, it will be found that between the temperatures 750°C. and 850°C.

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a very small increase in the current produces an enormous increase in the voltage—a fact which has been utilised in constructing "ballasting" resistances for Nernst lamps.* At Ar_3, the electrical resistance of iron practically ceases to increase with the temperature, so that γ ferrite is characterised by possessing an electrical resistance which is independent of the temperature; it is also non-magnetic.

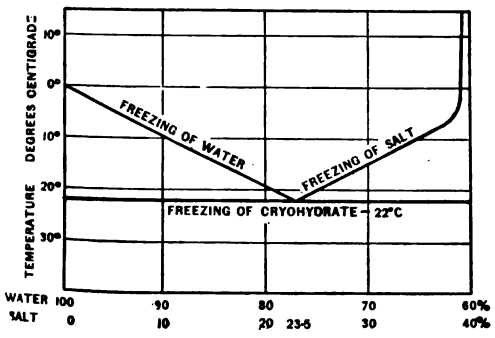

FIG. 2.—CURVES FOR SALT SOLUTIONS.

IF we obtain the cooling curves for samples of steel of different carbon contents, it is found that the transition point Ar_1 occurs at a practically constant temperature (660° C.), whatever may be the carbon content. On the other hand, an increase in the carbon content causes the points Ar_3 and Ar_2 to occur at lower temperatures, these temperatures gradually approximating to each other as the carbon content increases, till with steel containing about 0·3 per cent. of carbon the two points Ar_3 and Ar_2 coalesce. As the carbon content is still further increased, the arrest point corresponding to the coalescence of Ar_3 and Ar_2 occurs at lower and lower temperatures, until when the carbon content reaches about 0·89 per cent., only one arrest point (Ar_1) can be observed. Fig. 3 shows the way in which the arrest points of steel vary with the carbon content; taking any given percentage of carbon, a vertical line drawn through the corresponding scale division (read from the lower line of figures under the horizontal axis) will cut the curves in the various arrest points. The two branches corresponding to Ar_3 and Ar_2 are seen to run into each other, subsequently coinciding in the inclined branch which cuts

Constitution of Steel

* "Electric Lamps," by James Swinburne, M.I.C.E., TECHNICS, Vol. II., No. 10, October, 1904, page 353.

the curve for Ar_1 at a point corresponding to 0·89 per cent. of carbon. When the steel contains more than 0·89 per cent. of carbon, two arrest points are observed: one corresponds to Ar_1, and the other occurs at a higher temperature, which rises as the carbon content increases. This is indicated by the upward sloping line rising from the point on Ar_1 corresponding to a carbon content of 0·89 per cent.

To appreciate the significance of the curves given in Fig. 3, it is best to refer to the similar curves for an aqueous solution of common salt (Fig. 2). Pure water freezes at 0°C., but the addition of salt lowers the freezing point. If an aqueous solution containing 10 per cent. of common salt is cooled, it is found that pure ice first separates out, and this process continues until the solution attains a concentration of 23·5 parts by weight of salt in 76·5 parts by weight of water; if the temperature then falls, the solution remains liquid till a temperature of −22°C. is reached, when it suddenly becomes solid. Guthrie, who first studied these phenomena, observed that the proportions of salt and water in the solution which finally solidified, satisfied the formula $NaCl + 10H_2O$, and assumed that a hydrate of this composi-

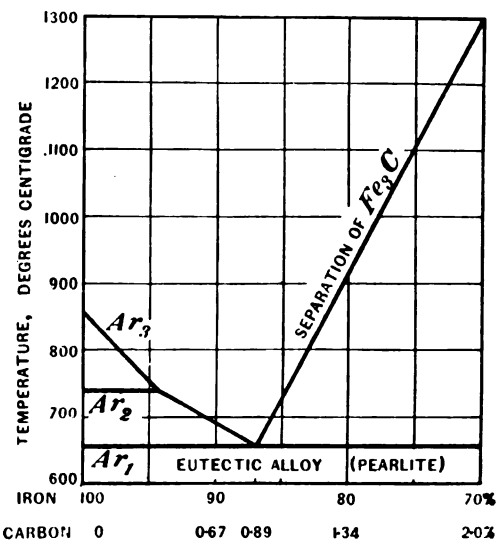

FIG. 3.—CURVES FOR STEEL.

tion was formed; to this he gave the name of a *cryohydrate*—meaning a hydrate which could exist only at low temperatures. It has subsequently been proved, by microscopical examination, that the cryohydrate consists of an intimate mixture of ice and salt. Thus, if

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we cool a solution containing less than 23·5 per cent. of common salt, pure ice forms at some temperature between 0° and − 22°C. (Fig. 2), and the mother liquid finally crystallises out at − 22°C. in the form of an intimate mixture of ice and salt crystals. If the original solution contains more than 23·5 per cent. of salt, the salt first crystallises out, leaving as before a mother liquor containing 23·5 per cent. of salt, which crystallises out as an intimate mixture of ice and salt crystals at − 22°C.

In the case of steel, similar phenomena occur. When the steel contains less than 0·89 per cent. of carbon, pure iron or *ferrite* segregates at a temperature depending on the concentration, leaving a solid solution of 0·89 parts of carbon in iron, which separates into an intimate mixture of Fe_3C (or *cementite*) and ferrite, at a temperature of 660°C. This intimate mixture of cementite and ferrite has been called *pearlite* on account of its iridescent appearance under reflected light, due to the fact that the constituents are associated in minute flakes: pearlite is said to be the *eutectic alloy* of iron and carbon, or the alloy possessing the lowest temperature of separation: its analogy with a cryohydrate is sufficiently obvious. When the salt solution is cooled, the pure ice or salt which first separates out may be removed, so that the cryohydrate may be ultimately obtained by itself. In the case of steel we are dealing with a solid solution; consequently, when the steel contains less than 0·89 per cent. of carbon, the microscope reveals the structure to consist of areas of ferrite surrounded by tracts of pearlite, or areas of pearlite surrounded by ferrite, according as the carbon content is very small or approaches 0·89 per cent. When the carbon content is equal to 0·89 per cent., the slowly cooled steel consists merely of pearlite, which separates out at 660°C. If the carbon content exceeds 0·89 per cent., cementite (Fe_3C) first separates out (Fig. 3), just as salt does in strong saline solutions; the ultimate constitution of the slowly-cooled steel will therefore consist of areas of free cementite surrounded by tracts of pearlite, or *vice versâ*.

Nickel Steel

Fig. 3 shows that carbon added to iron considerably modifies the nature of the allotropic transformations which can occur. So long as the carbon content does not exceed about 0·3 per cent., the transformations from γ to β, and from β to α ferrite occur separately; but for larger percentage of carbon the transformations occur simultaneously, as indicated by the curves for Ar_3 and Ar_2 coalescing into a single curve cutting the Ar_1 curve at a point corresponding to a carbon content of 0·89 per cent. From this it appears that when steel containing 0·89 per cent. of carbon is heated, the transformation into γ ferrite will occur at about 660°C., and for all higher temperatures the iron will be non-magnetic. More remarkable still are the changes produced by the addition of nickel to iron. In this case the transformation from α to β and γ ferrite occurs at a very low temperature; with alloys containing from 26 to 27 per cent. of nickel, the transformation point occurs at about 0° C., so that a nickel steel of this constitution is non-magnetic at ordinary temperatures. With larger percentages of nickel, the temperature at which the steel becomes non-magnetic rises with the percentage of nickel. Speaking generally, the presence of nickel alloyed with iron tends to depress the temperature at which α ferrite changes into β and γ ferrite; further, the transformations from α to β and from β to γ ferrite are not completed at any particular temperature or temperatures, but both these transformations progress simultaneously over a range of temperature which may be as great as 100°C. This leads to very important results. The transformation from β to γ ferrite is accompanied by a considerable contraction; in nickel steel, where the transformations from α to β and from β to γ ferrite progress simultaneously as the temperature rises, the normal expansion of α and β ferrite is wholly or partially compensated by the contraction due to the transformation from β to γ ferrite, or this contraction may mask the expansion of the α and β ferrite. Consequently, it is possible, by adding suitable proportions of nickel, to obtain steel which expands, remains constant in dimensions, or contracts as the temperature rises. M. Ch. Ed. Guillaume, who has carefully investigated the properties of nickel steels, finds that a steel containing 36 per cent. of nickel is practically inexpansible: the name *invar* has been given to this alloy.

Invar: its Technical Uses

A clock pendulum made from invar needs no compensation, since its length is unaffected by variations of temperature. It is found that a rod of invar very slowly increases in length when kept at a constant temperature; this change extends over many years, but is not of sufficiently large

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magnitude to form a drawback to the use of invar in ordinary instruments of precision, although it renders this substance unsuitable for the construction of ultimate standards of length. Invar is destined to play an important part in ordinary geodetical measurements: here the small progressive expansion mentioned above is of little consequence, since the standards of length can be periodically compared with an ultimate standard; on the other hand, the increase in accuracy is very marked. M. Guillaume has designed and constructed invar standards 4 meters long, of an H section with a 40 mm. side; these are enclosed in aluminium cases, the whole of each weighing only 56 kgs.: the older form of standard, consisting of two scales and a rigid support, weighed 72 kgs. without any containing case. For field measurements invar wire standards 24 meters in length can now be used; an accuracy approaching 1 in 1,000,000 is thus attained without using any correction for temperature. The wire, which is 1·65 mm. in diameter, can be wound on any drum exceeding 50 cms. in diameter, so that it can be readily transported; in use, the wire is stretched by a constant load not greater than 20 kgs. At present, ten men using an invar wire standard can proceed in the measurement of a base line at the rate of 5 kilometers per day; previously, fifty men using rules and microscopes could only proceed at the rate of 0·5 kilometer per day. In the future, the measurement of angles in geodesy will be controlled by the use of several long bases; while in the past the tendency was to reduce the number of base measurements as much as possible, by using numerous angular measurements.

It has further been found that steel containing 45 per cent. of nickel possesses the same coefficient of thermal expansion as glass, with the result that nickel-steel wires of this constitution can be used for sealing into incandescent lamps, instead of the platinum wires heretofore used. Several manufacturers of incandescent lamps are now using this alloy of nickel and iron, under the name of *platinite;* it has been estimated that by this means a ton of platinum will be saved per annum.

Use of Nickel Steel in Horology

We have not yet exhausted the interesting properties of nickel steel. When α or β ferrite is heated, its elasticity diminishes; on the other hand, a great increase in elasticity accompanies the transformation from β to γ ferrite. Thus, by choosing a suitable alloy of steel, we can construct a spring of which the elasticity (Young's modulus) diminishes, remains constant, or increases with the temperature. Now the time of vibration of the balance wheel of a watch depends upon the ratio of the moment of inertia of the wheel to the Young's modulus of the hair spring:* so long as this ratio remains constant the balance wheel vibrates with a constant period. A rise of temperature causes the metal of which the balance wheel is composed to expand, so increasing the moment of inertia of the balance wheel; at the same time it causes the elasticity of the spring to diminish. Both these effects tend to increase the time of vibration, but the decrease in the elasticity of the spring is the more important; a rise of temperature from 0° to 30° C. will cause a watch with a monometallic balance wheel and a steel spring to lose five minutes per day. By using a nickel-steel hair-spring of such constitution that the elasticity is constant, 90 per cent. of this inaccuracy can be removed, and the cost of roughly compensating the watch can be reduced 50 per cent.

Nickel steel may also be used in connection with marine chronometers, where the greatest accuracy is desirable. In the past these chronometers were compensated by the use of a compound balance wheel: the rim of the wheel was made in segments fixed only at one end, each segment consisting of an inner strip of steel and an outer strip of brass. A rise of temperature produces a greater expansion in the brass than in the steel, with the result that the free end of the segment curls round and approaches the centre of the wheel, thus diminishing the moment of inertia. The compensation was so adjusted that at the two extremes of temperature to which the chronometer was likely to be subjected, the ratio of the moment of inertia of the balance wheel to the Young's modulus of the spring had equal values. In this case the chronometer keeps correct time at either of these extreme temperatures; but the celebrated English watchmaker, Dent, found, in 1833, that it gains for intermediate temperatures. The cause of this is that the decrease in the elasticity of the spring is not strictly proportional to the rise of temperature; the elasticity diminishes more and more quickly as the temperature rises. On the other hand, the decrease in the moment of inertia of the compensated balance wheel is sensibly pro-

* Technics, Vol. III., No. 13, pp. 93-95.

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portional to the rise of temperature. Thus, if the compensation is arranged so that the moment of inertia of the balance wheel bears a constant ratio to the elasticity of the spring at the two extreme temperatures, the ratio will not be constant for intermediate temperatures, but will diminish, reach a minimum, and then increase as the temperature rises. This source of error can be practically removed by using a steel spring, together with a compensated balance wheel in which a strip of nickel steel replaces the ordinary steel heretofore used. The nickel steel is chosen so that its expansion increases more and more slowly as the temperature rises, with the result that the segments of the wheel curl round more and more quickly, and decrease the moment of inertia of the wheel at a greater and greater rate, as the temperature rises. In this way the unavoidable error of a chronometer has been reduced to about one-tenth of its previous value. A chronometer, made on these principles by M. P. Ditisheim, when tested by the Kew committee in 1903, was awarded 19·7 marks out of a possible 20.

Recent Chemical Apparatus

At the recent Earl's Court Exhibition Messrs. Townson and Mercer exhibited an improved aspirator and measure devised by Mr. H. L. Greville. The improvements consist in the substitution of a graduated glass vessel for the usual opaque unmeasured one, and the provision of a stopcock by which the flow of gas can be accurately regulated.

The regulation of the flow of water is obtained by a glass receiver which may be placed at any desired level. The instrument is specially suited for use with Harcourt's colour-test, for CO_2, H_2S, and CS_2 in gases.

An apparatus devised by Herr Becker, chemist to the Frankfort Gas Company, for the purpose of estimating water in tar, is shown in the subjoined illustration (Fig. 4). The method depends on heating under reduced pressure, in order to overcome the bumping and frothing which occur under atmospheric pressure; and as a consequence the operation is performed more safely and expeditiously. A is a flask of one gallon capacity. C is a Liebig's condenser, the central tube of which is continuous with the worm of the condenser D, which worm opens into the receiver E. V is a vacuum flask, connected with an air pump worked by a jet of water. V is connected with a manometer M, and with the bulbs in H, and thereby with E. Another water supply flows through H into C, thence by J to D, and away to waste at O. At I and K are pinch cocks opening to the outer air. About 2¼ lbs. of tar is put into A, the stopcock I is closed, and K opened; the tar is heated until it begins to give off numerous small bubbles. K is then closed, and

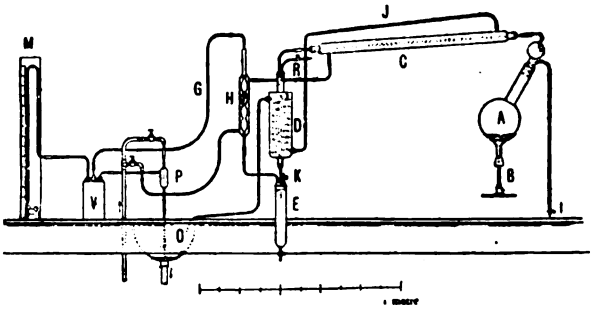

FIG. 4.—BECKER'S APPARATUS FOR ESTIMATING WATER IN TAR.

the air pump adjusted to give a sixteen inch mercury column. The tar soon begins to froth violently, but is checked by a short squeeze at I, which promptly drives back the froth. This is repeated until the tar is tranquil, indicating the complete removal of water. On raising the vacuum to twenty-eight inches, and further heating, the tar gives off oils: the blackened walls of the flask are washed clear. When this occurs the heating is stopped, I is opened, and the air pump slowly put out of action. The water stands below the oil in E, and may be run off and weighed. If by chance any of the froth gets up into the condenser C, open not the stopcock I, but R; air runs in and drives the froth back from C into A. The vacuum must be kept well up, so that the admission of the outer air may have the effect of repressing the froth; if the frothing is too vigorous, it may prove necessary to lower the flame. The apparatus can also be used for estimating the oils.

In a note on "Soils and Subsoils" (TECHNICS, Vol. III., No. 13, p. 3), the price of the new geological maps on a scale of an inch to the mile was given as 7s. 6d. instead of 1s. 6d. each, their true price. We are anxious to rectify the error, since the usefulness of the maps is much enhanced by their cheapness.

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THE FIBROUS CONSTITUENTS OF PAPER.

By CLAYTON BEADLE.

Illustrated with photo-micrographs by John Christie, F.R.M.S.

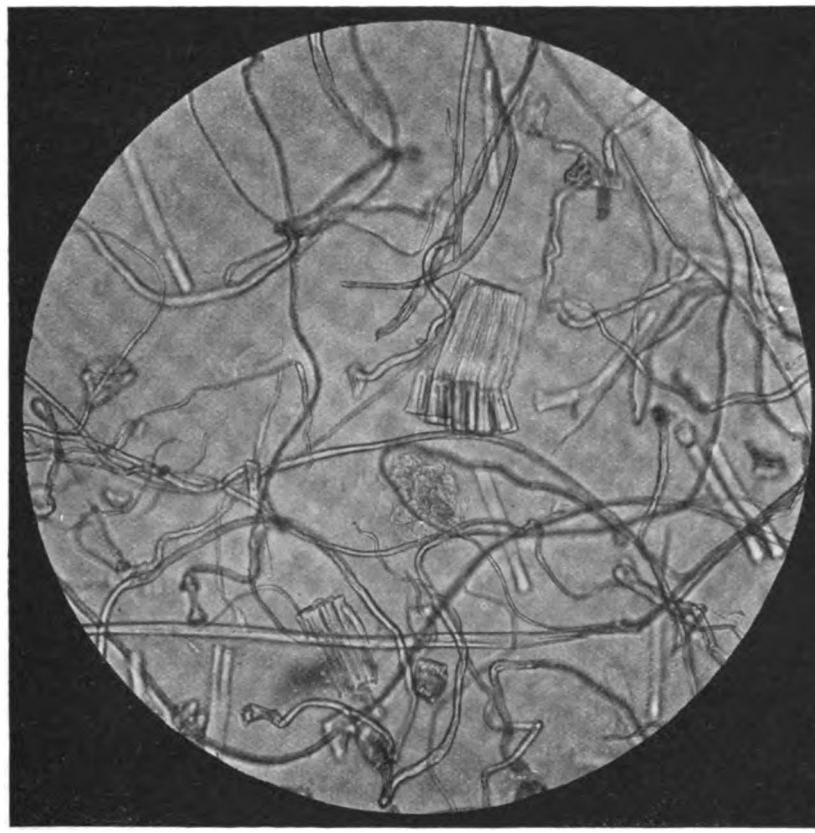

FIG. 1.—INDIAN UNRIPE COTTON FIBRES WITH BLEACHED HUSK.

(*Magnified 90 diameters.*)

Prepared from "Cotton Hulls" by separation, boiling and bleaching. These fibres are much smaller than the unripe Egyptian, and more firmly attached to the husk by means of the trumpet-shaped ends. The bleached husk-cells are well shown near the centre. The unripe fibres are generally zig-zag and entangled; their central canals are almost imperceptible. The husk-cells are angular and columnar, and the length of these cells represents the thickness of the husk. Their individual characteristics are not easily discerned in the untreated state. The colouring matter of the husk, with which these cells are permeated, must be removed by drastic chemical treatment to admit of the cells being separated and rendered invisible in paper pulp. In the dried bleached pulp they can be separated from the cotton fibres by sieving. They are heavy and granular in the dry state. The colour reactions of the bleached husk-cells, when examined under the microscope, are distinct from those of the cotton fibres, but, like the latter, they are capable of withstanding very drastic chemical treatment.

MONSIEUR MARCEL ROSTAING wrote me on October 20th as follows: –

"It would be interesting to notice that when a pull is applied to a strip of tubsized paper by means of the paper-testing machine, the point of fracture always takes place in the middle of the strip, when tested according to machine direction, and near the jaws, very exactly at the same point, when tested according to cross direction."

I have carefully preserved the fractures obtained in my researches for this series of articles. After looking through these carefully, I am compelled to admit that my results,

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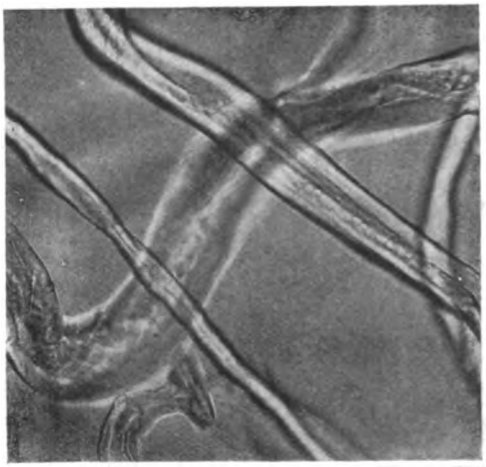

which cover a fairly wide field and extend into hundreds of tests made on different kinds of paper, do not on the whole confirm Rostaing's views. I can, on the other hand, find many instances of fractures that behave as Rostaing describes, but there are many that do *not* do so. I conclude, therefore, that with certain papers Rostaing's remarks hold good, but other papers do not obey this rule, and as a consequence no definite law can be deduced from it. By comparing the fractures of strips cut at different

FIG. 2.—INDIAN UNRIPE COTTON FIBRES.
(*Magnified 325 diameters.*)

Showing zig-zags, and trumpet-shaped end (near bottom of picture), by means of which the fibres attach themselves to the husk.

FIG. 3.—EGYPTIAN UNRIPE COTTON FIBRES FROM HULLS.
(*Magnified 90 diameters.*)

Showing trumpet-shaped butt-ends as detached from husk, and bleached cluster of husk-cells. Note that many of the unripe fibres are nearly solid, and do not show spiral twistings, as with ordinary mature fibres. The cell walls were too thick to permit them to collapse and twist. The above elements were separated from the cotton hulls after having been mechanically deprived of loose husk, after which they were boiled under pressure and bleached. The husk cells have no felting qualities, and therefore do not give strength to paper, behaving as so much inert matter. Unripe cotton fibres behave very differently from the mature fibres. They work very free on the paper machine, and produce a spongy paper, and behave very differently towards chemical reagents. As with Indian cotton fibres, these generally present a very zig-zig entangled appearance.

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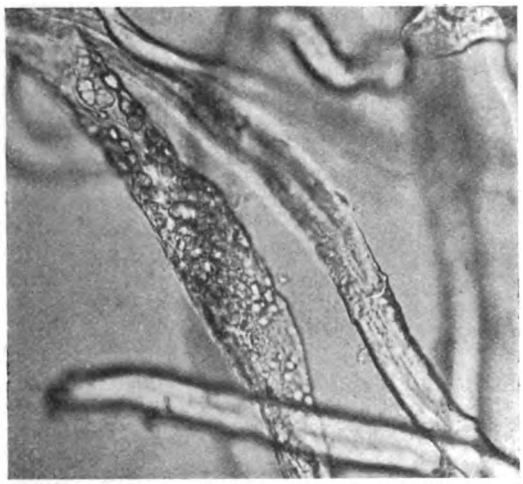

FIG. 4.—EGYPTIAN UNRIPE COTTON FIBRES.
(*Magnified 325 diameters.*)
Focussed to show warty protuberances, often noticed in the isolated bleached Egyptian product derived from the hulls.

angles (the fan method) some extremely interesting results are obtained *with any one paper*. But when one comes to compare the results obtained with different classes of paper, or even with different makes of the same class of paper, the lines of fracture may be, and often are, quite different. We cannot be too cautious; and, therefore, with a variable substance like paper, we must perform a large number of tests before we can arrive at any definite conclusion. Our conclusions, when arrived at, must be stated only with very definite limitations, otherwise we shall find that later on it will be necessary for us to retract either a portion or the whole of our statement.

The accompanying photo-micrographs are sufficiently explained by their underlines. I should like, however, to mention that those photo-micrographs showing the peculiar method of distinguishing fibres by

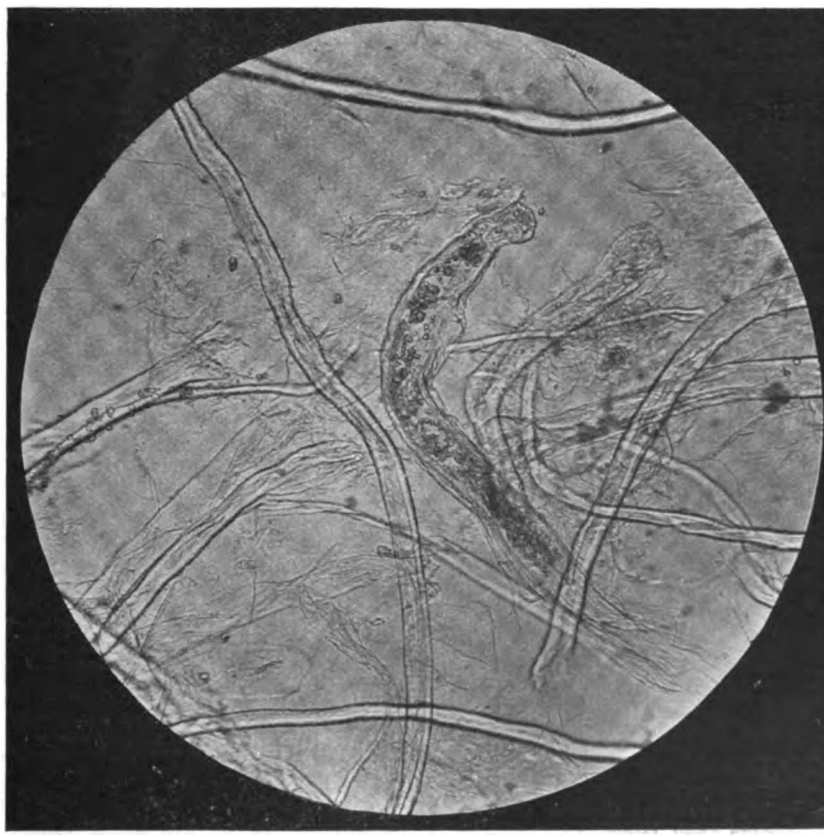

FIG. 5.—FIBRES OF PAPER MADE FROM AMERICAN COTTON HULLS.
(*Magnified 150 diameters.*)
Showing in centre the granular nature of the butt ends which have been detached from the husk during the mechanical and chemical treatment to which the hulls have been subjected during their manufacture into paper.

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FIG. 6. — FIBROUS ELEMENTS OF PAPER MADE ENTIRELY FROM BOILED AND BLEACHED AMERICAN COTTON HULLS.

(*Magnified 90 diameters.*)

Note dark portion near the centre containing the supposed granules. Note also great difference between the American and the Indian and Egyptian cotton fibres derived from hulls.

FIG. 7.—VERY THIN, PURE COTTON TISSUE PAPER, SEEN THROUGH.

(*Magnified 90 diameters.*)

This paper is manufactured for the purposes of nitration, and consists of nothing but absolutely pure cotton fibres. Notice that the fibres tend very much in the machine direction; *viz.*, in a vertical direction.

boiling in hard water and allowing to cool were made at the instance of Mr. Christie. It is somewhat strange that when cotton and linen beaten fibres, after boiling in hard tap water, are allowed to cool, the crystals of carbonate of lime surround only the linen and not the cotton fibres. This test was repeated with similar results. It would not do, however, to conclude that this is always the case with mixtures of cotton and linen fibres, nor do we think it is. At present we have no possible explanation of this phenomenon.

The photo-micrographs on the "Standard Record Paper" have been added in consequence of information supplied to me, in the first instance, by Dr. B. F. Davenport,

FIG. 8.—TRANSVERSE SECTION, IN MACHINE DIRECTION, OF PURE COTTON TISSUE PAPER (same as Fig. 7).

(*Magnified 325 diameters.*)

Treasurer to the American Chemical Society (North Eastern Section), and also on account of the information and reports submitted to me by Mr. Robert T. Swan, Commissioner of Public Records in the State of Massachusetts. The information contained in these reports forced me to the conclusion that, in respect of this very important matter, the United States are much ahead of this country, and our Government would do well to imitate their most excellent example. I hope to dwell upon this matter more fully on some future occasion.

The photo-micrographs showing the characteristics of the fibres and "vessels" obtained by treating cotton hulls, either the Egyptian, Indian, or American product, have also been added as illustrating a subject to which I have for many years devoted much

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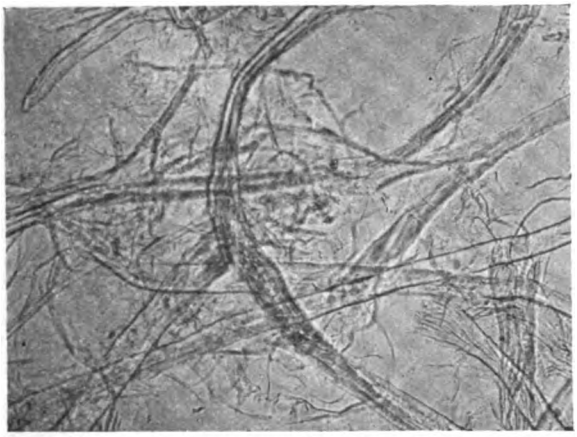

FIG. 9.—FIBROUS ELEMENTS OF "STANDARD RECORD PAPER."
(*Magnified* 150 *diameters.*)

Mounted in glycerine. This paper is used by order of the Senate for public records for the State of Mass., U.S.A.; it consists of pure linen and new cotton fibres in almost equal proportions, and is prepared to specification by a few leading American firms as the result of exhaustive investigations and enquiry made by the State.

time and attention, especially in regard to the American product. If the "hulls" from either of these sources could be converted into paper and be made to pay, we should be provided with a large supply of raw material, which at present is for all intents and purposes a waste product. The results of recent researches in this direction have been encouraging, but success has not yet been achieved. Any work or information on this subject should, however, be regarded favourably, as it might tend towards the solution of this important problem.

The photo-micrographs of a pure cotton paper, the only one which I have ever been able to procure, have been added, in order that the same may be contrasted with those of a pure linen paper already published in this series; and, lastly, a photo-micro-

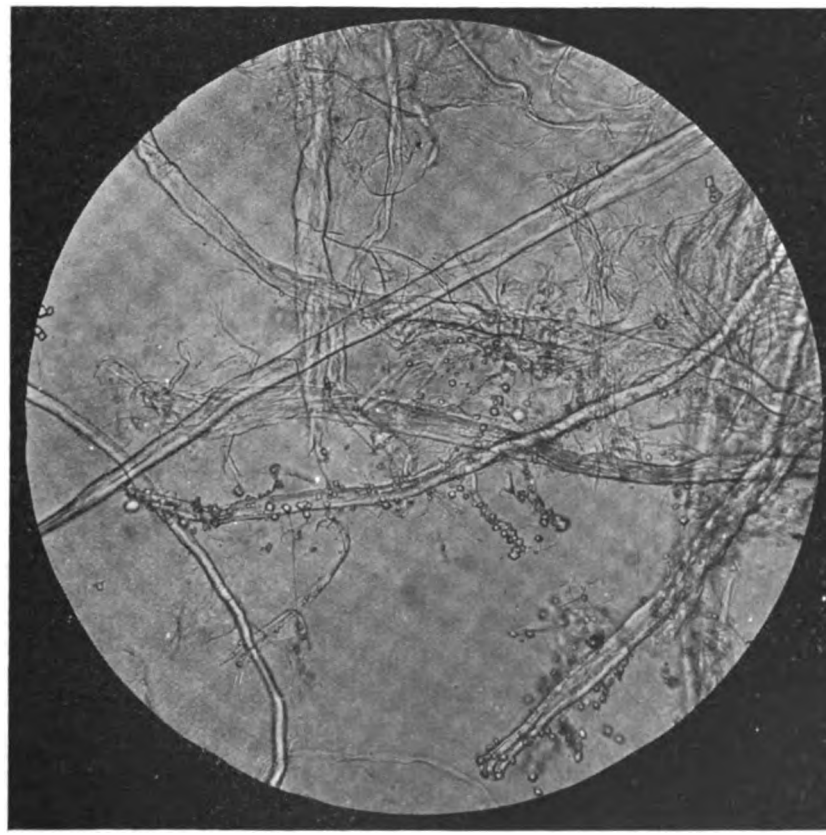

FIG. 10.
(*Magnified* 150 *diameters.*)

The same as Fig. 9, but mounted by boiling fibres in London tap water (containing fifteen grains per gallon of carbonate of lime), and allowing the water to gradually cool. It is of extreme interest to note that the carbonate of lime from the hard water has crystallised round the linen fibres, but not round the cotton.

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graph of the transverse section of leaf of boiled Esparto grass has been added. This is the recent work of Mr. John Christie, and would have appeared in the section devoted to Esparto had it been available at the time.

We hope later on to focus critically into the regions of the vascular area, with a view to ascertaining what has become of the "vessels" which appear in the present photo-micrograph to be obliterated by the chemical treatment. The selective action of the soda boil is well brought out in this photo-micrograph.

FIG. 11.—COTTON AND LINEN FIBRE, AS IN FIG. 10.
(*Magnified* 325 *diameters.*)
Showing how the crystals of carbonate of lime surround the linen, but not the cotton.

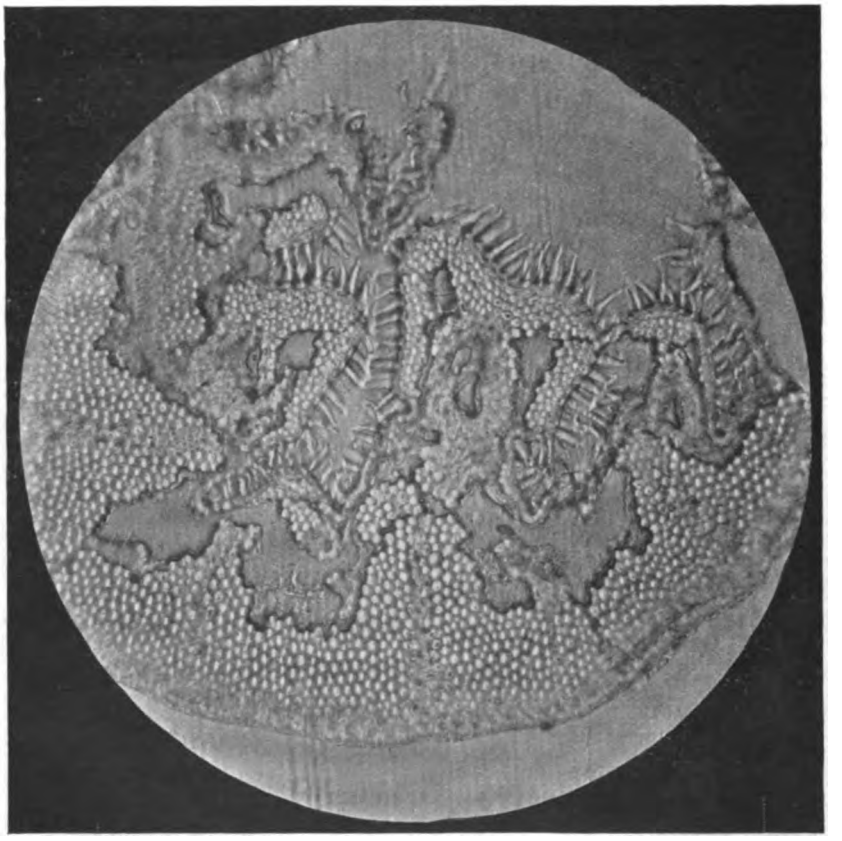

FIG. 12.—BOILED ESPARTO GRASS IN TRANSVERSE SECTION.
(*Magnified* 18 *diameters.*)

Showing that the "vessels" have gone beyond recognition; also that the purer fibres have swelled up under the action of the alkali. The lignified bands of fibres, running from the cuticular cells towards and surrounding the vascular area have undergone alteration. This section shows generally the selective action of the soda boil upon the different elements of the Esparto leaf, and should for this purpose be compared with photo-micrographs of sections of unboiled leaf, as shown in the May number of TECHNICS.

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART V.—THE MAGNETIC CIRCUIT.

By EDWIN EDSER, A.R.C.Sc.

IN the January number of TECHNICS I explained some of the fundamental properties of the electric circuit. It was there shown that the magnetic field due to a current flowing along a very long straight conductor consists of circular lines of force lying in planes perpendicular to the conductor; each circular line of force embraces the current, and is concentric with the section of the conductor. Thus there is no force acting on a pole in a direction parallel to the conductor, and no force in the direction of the perpendicular let fall from the pole on to the conductor. If a unit N pole is placed at A (Fig. 1) in the neighbourhood of a

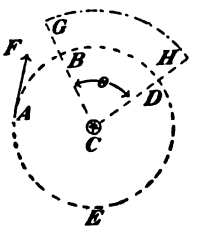

FIG. 1.

conductor carrying a current C vertically downwards through the plane of the paper, the force F acting on it has the direction of the arrow AF, drawn as a tangent to the circular line of force ABDE. The magnitude of the force F acting on the unit N pole was proved (TECHNICS, No. 13, January, 1905, page 45) to be equal to $2C/r$, where C is the value of the current, in c.g.s. units, and r is the perpendicular distance of the point A from the conductor.

If we move the unit N pole round the circle AEDBA (Fig. 1) the force F acting on the pole at each point will directly oppose its motion, so that the work done in moving the pole round the circle is equal to

F × *circumference of circle* AEDBA, or

$$\frac{2C}{r} \times 2\pi r = 4\pi C.$$

Now, this result is independent of r, the radius of the circular path; consequently the work done in moving a unit N pole round *any* circle concentric with the conductor, lying in a plane perpendicular to the conductor, is equal to $4\pi C$. If, in Fig. 1, the N pole is moved in the direction AEDBA, work must be performed by the agent moving the pole; this work is converted into energy supplied to the electric current. To be quite clear on this point, notice that carrying the N pole in an anti-clockwise direction around the conductor produces the same effect as keeping the pole stationary and moving the conductor around it in an anti-clockwise direction; when the conductor is moved and the pole is maintained in a fixed position, the lines of force from the N pole will be bent round in front of the conductor, so as to oppose its motion, thus indicating the production of an E.M.F. acting downwards through the plane of the paper, or *in* the direction of the current C.

On the other hand, if a unit N pole, free to move round the circle ABDE, were placed at A, it would travel round the circle in a clockwise direction, and in every revolution the current would perform on the pole an amount of work equal to $4\pi C$. In this case it is easily seen that an E.M.F. *opposing* the current will be generated in the conductor; in order that the current may be maintained constant, the battery or other arrangement supplying the current must produce an amount of energy in excess of that dissipated in heating the conductor and the rest of the circuit, this excess amounting to $4\pi C$ ergs for every revolution of the unit N pole.

Let GH be an arc of a circle of radius $CG = r_1$, drawn about C as centre. Let the angle $GCH = \theta$, and let the radii GC and HC cut the circle ABDE in the points B and D. Then the arc $BD = r\theta$, while the arc $GH = r_1\theta$. It is easily seen that the work done in moving a unit N pole from G to H, is equal to that done in moving the pole from B to G. For the force opposing the motion of the pole during its passage from G to H is equal to $2C/r_1$, and $GH = r_1\theta$; therefore, work done $= (2C/r_1) \times r_1\theta = 2\theta C$. Similarly the work done in traversing the path $BD = (2C/r) \times r\theta = 2\theta C$. Conse-

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quently, if a unit N pole is moved round the path BDHGB, so as to return to the point whence it started, there will be no resultant work performed. In passing from B to D, the current will perform $2\theta C$ ergs of work on the pole; in passing along the radial element of path DH no work will be performed, since the direction of motion is perpendicular to the force acting on the pole; in passing from H to G, the agent moving the pole must perform $2\theta C$ ergs of work, the corresponding amount of energy being returned to the electric circuit; finally, no work is performed in passing from G to B. Thus, the unit N pole gains $2\theta C$ ergs of energy in passing from B to D, and loses $2\theta C$ ergs in passing from H to G.

Let ABD (Fig. 2) be a closed curve of any shape, drawn so as to embrace a conductor carrying a current C, the direction of the

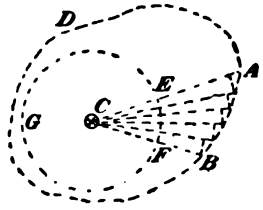

FIG. 2.

current being perpendicular to the plane in which the curve is drawn; then it is easily proved that the work done in moving a unit N pole round the closed curve ABDA is equal to $4\pi C$. With centre C and any radius draw the circle EFG. Divide the portion AB of the given curve into small elements by means of radii drawn from C, and resolve each element into a small radial portion together with a small circular arc, as shown in Fig. 2. Then, if the elements are small enough, the portion AB of the curve will be indistinguishable from the series of steps, each consisting of a small radial portion and a small circular arc, into which AB has been resolved; therefore, the work done will be the same, whether we carry the unit N pole along the curve AB, or along the series of infinitesimally small steps. Now, in carrying the unit N pole over one of the steps, no work will be done in traversing the radial portion; and in traversing the circular arc the work done will be equal to $2\theta C$, if the circular element subtends an angle θ at C. Hence, if there are n steps between A and B, and each circular element of a step subtends an angle θ at C, the work done in carrying the pole from A to B will be equal to $2n\theta C$, where $n\theta$ = angle ACB. But the work done in carrying the unit N pole from E to F along the circular arc EF is equal to $2C \times$ angle ACB; hence, we conclude that in carrying the unit N pole once round the closed curve ABDA, the work performed will be equal to that required to carry the pole round the circular path EFGE, *i.e.*, to $4\pi C$. If the unit N pole were carried round a curve which does not embrace the current, the work done would be equal to $4\pi \times 0 = 0$.

We may now consider the more general case, where a unit N pole is carried round *any* closed curve ABDE, Fig. 3, embracing a long straight conductor carrying a current C; this curve need not lie in a plane perpendicular to the conductor, and indeed need not lie in any plane. Project the curve ABDE on to a plane perpendicular to the conductor,

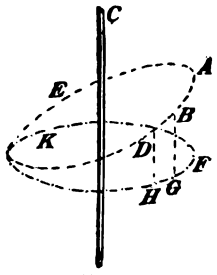

FIG. 3.

thus obtaining the curve FGHK. Let GH be the projection of BD; then since the closed path BGHD does not embrace a current, there will be no resultant work performed in carrying a unit N pole round BGHDB. The straight lines BG and DH are perpendicular to a plane which is itself perpendicular to the conductor; hence these lines are parallel to the conductor. Since no force parallel to the conductor acts on the pole, no work will be performed in traversing either BG or HD. Thus the work done in traversing DB and GH must be equal to zero, or the work done in traversing DB is equal and of opposite sign to that done in traversing GH; in other words, the work done in traversing BD is equal to that done in traversing GH. Thus in passing round the closed curve ABDEA, the work done in traversing any element will be equal to that done in traversing the corresponding element of the curve FGHKF; therefore the total work performed in traversing the curve ABDEA is equal to the work performed in traversing the curve FGHKF. But, as already proved, in traversing the curve FGHKF drawn in a plane perpendicular to the conductor, the work done

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will be equal to $4\pi C$, where C is the c.g.s. value of the current flowing along the conductor. Hence we conclude that *in carrying a unit* N *pole round any closed curve which embraces a long straight conductor carrying a current* C, *the work done is equal to* $4\pi C$, *no matter what may be the shape or position of the curve chosen.*

An important distinction must now be drawn between the magnetic field due to an electric current and that due to a magnet. When a unit N pole is carried round an

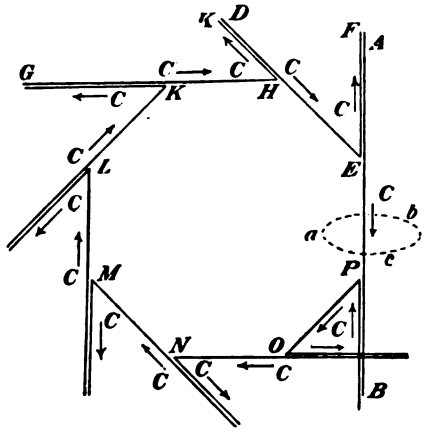

FIG. 4.

electric current, the electric circuit gains or loses energy according as the pole loses or gains energy; this is a direct result of the law of conservation of energy. If, however, a unit N pole is carried round a *magnet* in any path whatever, the magnet neither gains nor loses energy, since its condition remains unaltered throughout the process, and therefore the unit N pole can neither gain nor lose energy; in other words, *no resultant work is performed when a unit* N *pole is carried round any closed curve in a space where the magnetic field is wholly due to a magnet or any collection of magnets.*

The above reasoning, which depends on the assumption that the current flows along a very long straight conductor, must now be extended to the case where the conductor is bent into any required shape. Let AB, Fig. 4, be part of a very long straight conductor carrying a current C in the direction of the arrow; then in carrying a unit N pole once round the closed curve *abc* embracing the conductor AB, the work performed is equal to $4\pi C$. If we place a bent conductor DEF, carrying any current, in the neighbourhood of *abc*, the field at each point of the curve *abc* may be altered, but the alterations will be such that the work done in carrying a unit N pole round *abc* has the same value as before, *viz.*, $4\pi C$; provided, of course, that the curve *abc* does not embrace any part of the circuit DEF. To prove this, let us replace the circuit DEF by a plate of hardened steel of the same shape, magnetised so that one flat face has an N and the other an S magnetic polarity; then, by distributing the magnetism suitably, we may arrange that the lines of force leaving any particular point of the plate are precisely similar to those previously produced at the same point by the current C flowing along the circuit DEF; in this case the magnetised steel plate will produce a field at any point of the circuit *abc* exactly equal to that due to the current C flowing in the circuit DEF, and therefore the work done in moving a unit N pole round *abc* will be no more modified by the presence of the current C flowing along DEF than by the presence of the magnetised plate. But in moving a unit N pole round a closed curve, no extra work is performed if a magnet or a collection of magnets is brought into the neighbourhood; therefore no extra work is performed owing to the introduction of the circuit DEF carrying the current C.

Let us suppose that the conductor EF is placed side by side with a portion of the conductor AB, as in the figure, and that EF is extended indefinitely; then the magnetic field due to the current C flowing along EF in the direction from E to F will just neutralise the field due to the same current C flowing along the adjacent portion of the conductor AB in the direction from A to B; so that, so far as the magnetic field at any point of the curve *abc* is concerned, we may annul EF and the contiguous portion of AB, and suppose that the current C flows along the bent path DEB, the conductor DE being of considerable length.

In a similar manner we may add the circuit G H K, carrying a current equal to C in the direction of the arrow; then H K will annul the effect of the contiguous portion of D E, with the result that the current C may be supposed to flow along the path G H E B; as before, this will make no alteration in the work done in carrying a unit N pole round *a b c*. Proceeding in this manner, we may finally obtain a current C flowing along the polygonal path E P O N M L K H E, while the work done in carrying a unit N pole once round the closed curve *a b c* remains equal to $4\pi C$. Further, it is obvious that the sides of the polygon can be made as numerous, and each as small as we please, and the polygon can, therefore, be caused to approximate as closely

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as we please to any given curve; hence we conclude that *if an electric circuit has any shape whatever, the work done in carrying a unit N pole once round the current is equal to* $4\pi \times$ *the c.g.s. value of the current.*

If the circuit includes a number of loops, and a path is chosen embracing more than one of these loops, then the work done in carrying a unit N pole round this path is equal to —

$4\pi \times$ c.g.s. *value of current* $\times$ *number of loops embraced;*

for the work done in carrying the unit N pole round any loop must be added to that done in carrying it round the other loops.

The law just deduced is of considerable theoretical importance; it can, moreover, be used in obtaining results of great practical utility in a very simple manner, as I shall proceed to show. Let us first obtain the value of the magnetic field within a very long solenoid, round which circulates a current C. As a preliminary we must investigate the distribution of lines of force within the solenoid.

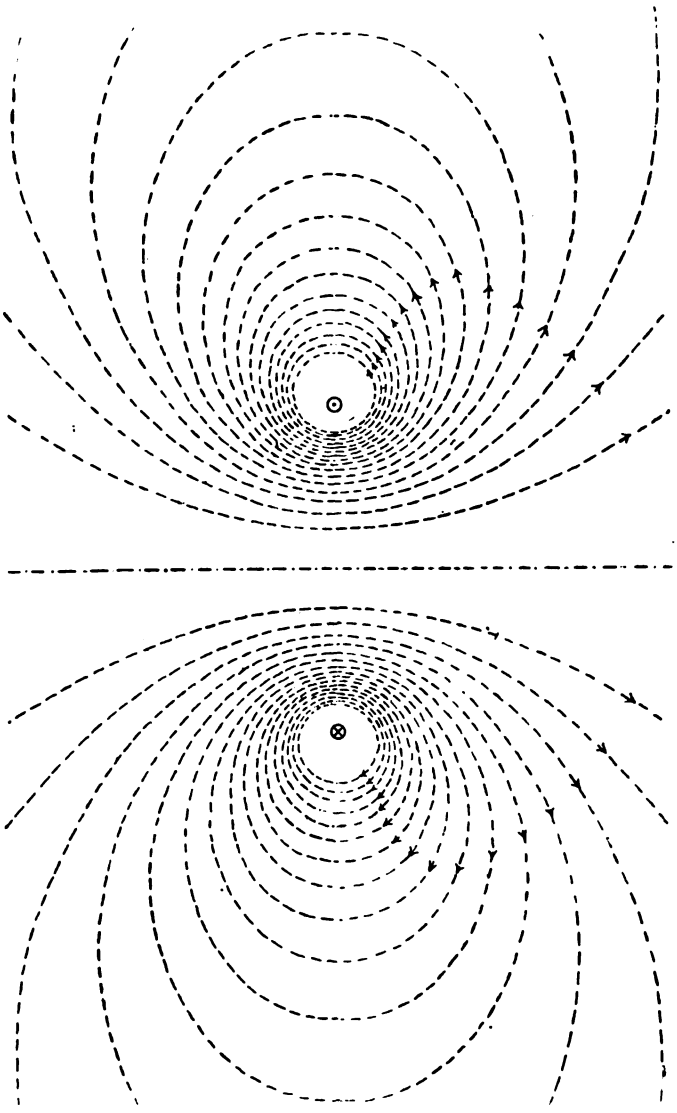

FIG. 5.—LINES OF FORCE DUE TO A CIRCULAR CURRENT.
The axis of the circular current is represented thus —·—·—·—

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The lines of force, due to a current flowing round a single circular turn of wire, are shown in Fig. 5. The small circles represent sections of the conductor at opposite sides of a diameter of the turn; the lines of force are somewhat like those due to equal currents flowing along straight and parallel conductors in opposite directions (TECHNICS, Vol. III., No. 13; Jan., 1905, p. 40), the chief difference being that the lines of force produced by the straight parallel currents are circles, while those due to the circular current are oval, the longer diameter of each oval being in the line joining the two sections of the conductors. It should be noted that the lines of force are greatly crowded near the conductor on the inside of the circuit; the tension of each line, combined with its curvature where it passes through the plane of the circuit, pulls the line strongly toward the conductor. We may infer from Fig. 5 that if the circular turn of wire were perfectly flexible and extensible, it would increase in diameter, the lateral pressure of the lines of force on the conductor causing the circuit to expand.

Fig. 6 represents the lines of force due to two co-axial circular turns of wire carrying equal currents in a uniform direction. The way in which many of the lines of force due to one turn link themselves on to lines due to the other turn, will be readily understood by the reader who has followed the previous articles on "The Electro-Magnetic Theory." From the disposition of the lines, it may be concluded that the two circular turns will apparently attract each other, and each will tend to expand. The lines, due to their curvature, are still somewhat crowded in the neighbourhood of the conductors; but as the lines of force within the turns are not so much curved as in Fig. 5, the crowding of the lines is less excessive. The closer the turns to each other, the greater will be the proportion of lines which embrace both turns; if we imagine the turns to be placed all but in direct contact with each other, practically all the lines will embrace both turns.

If we imagine a third turn of wire to be placed co-axially with the two represented in Fig. 6, the currents in all three turns circulating in a uniform direction, then a great number of lines of force will encircle all three turns, and these lines, in the space within the turns, will be more nearly straight, and therefore less crowded in the neighbourhood of the conductors.

A solenoid may be supposed to consist of a great number of co-axial circular turns placed very near to each other. If the solenoid is very long in comparison with its transverse dimensions, it is clear that the lines of force within it must be practically straight, and parallel to the axis of the solenoid, except in the immediate neighbourhood of the ends (Fig. 7). Now if the lines are straight, their longitudinal tensions can produce no forces perpendicular to their lengths, and therefore the only forces de-

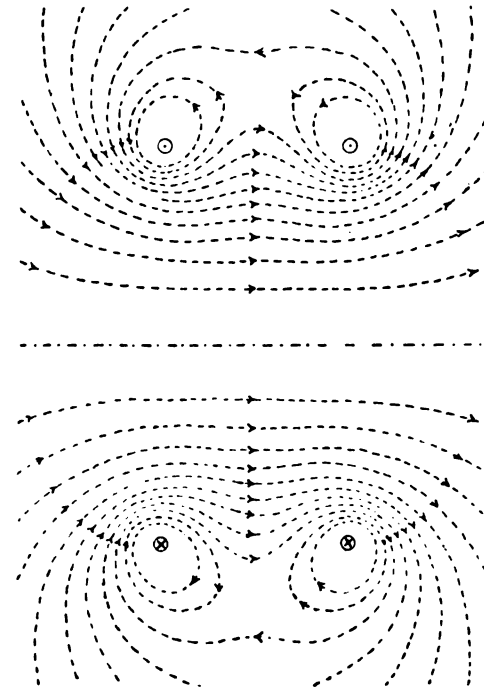

FIG. 6.—LINES OF FORCE DUE TO TWO CO-AXIAL CIRCULAR CURRENTS FLOWING IN THE SAME DIRECTION.

The common axis of the two circles is represented thus . — . — . — . — .

termining the positions of equilibrium of the lines must be their lateral repulsions. Further, as the pressure urging a tube of force to expand is inversely proportional to the sectional area of the tube, it follows that all tubes must be equal in sectional area in the space within the solenoid, or the lines of force (which represent the axes of the tubes of force) must be equi-distant one from another. But the number of lines of force passing normally through unit area at any point measures the field, or force per unit N pole at that point; hence, since the lines of force are parallel and uniformly distributed over the cross section of the solenoid, we con-

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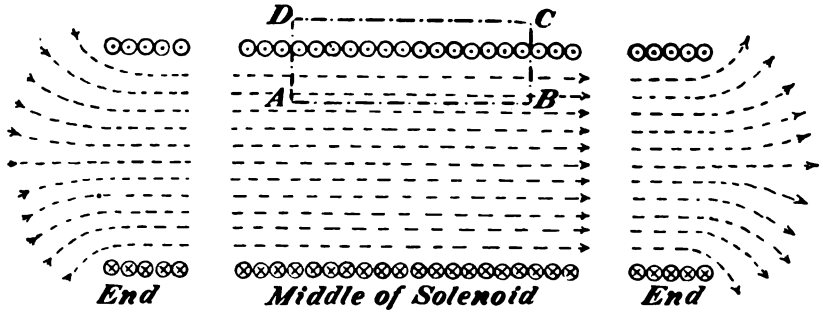

FIG. 7.—LINES OF FORCE WITHIN A SOLENOID.

clude that the field is uniform, both in direction and magnitude, at all points within, and not very near to, the ends of the solenoid.

To find the magnitude of the field within the solenoid, we may proceed as follows:—Draw the rectangular figure ABCD, Fig. 7, the side AB being one centimeter long, and drawn parallel to the axis of the solenoid or to the lines of force within this. If the figure ABCDA embraces n_1 conductors each carrying a current C (in c.g.s. units), then the work done in carrying a unit N pole round the path ABCDA is equal to $4\pi C n_1$. In carrying the unit N pole from A to B, in the direction of the lines of force, the work done on the pole is equal to $F \times AB = F \times 1$, if F is the magnitude of the field in dynes per unit pole. No work will be performed in carrying the unit N pole from B to C, since this path is perpendicular to the lines of force. The field outside the solenoid is equal to that produced by an N pole of suitable magnitude placed at one end, together with a numerically equal S pole placed at the other end of the solenoid. Now, if the solenoid is very long, its two ends will be so far removed from the middle of the solenoid that the field due to the lines of force leaving the ends (or to the magnetic poles which, if placed at the ends, would produce the same field outside the solenoid), will be inappreciably small at any point in the line CD. Hence, the work done in carrying a unit N pole from C to D will be so small as to be negligible. Finally, no work is performed in carrying the unit N pole from D to A. Thus the total work performed, in following the closed path ABCDA, is equal to F ergs per unit pole; and we have previously found the value $4\pi C n_1$ for the work done in following the same path. Hence, finally,

$$F = 4\pi C n_1,$$

or, in words, *the field within a solenoid which is very long in comparison with its transverse dimensions, is equal to* 4π *times the current circulating round the solenoid, multiplied by the number of turns per unit length of the solenoid.*

We have heretofore supposed that the medium in which the unit N pole and the conductor carrying the current are immersed is non-magnetic ($\mu = 1$). Let us now suppose that a current C flows downwards through the plane of the paper (Fig. 8) along a very long, straight conductor lying on the axis of a cylindrical hole or tunnel in a magnetic medium of permeability μ; that is to say, the medium within the circle ABD (Fig. 8) is non-magnetic, while the medium outside this circle has a permeability equal to μ. Let CE, CF be any two radii, while EF and GH are two circular arcs drawn with C as

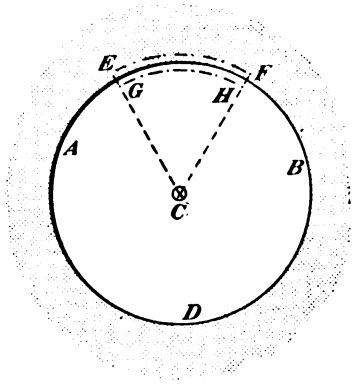

FIG. 8.

centre, the one just within and the other just without the circle ABD; we may suppose that the arcs EF and GH are so close together that, if both were in the same medium, the fields along both would be sensibly equal, as would also be the lengths of the arcs. In carrying a unit N pole round the closed path GHFEG, the resultant work done must be equal to zero, since no current is embraced; hence, the work done in going from E to F must be equal to that performed in going from G to H; and since the arcs EF and GH are supposed to be sensibly equal in length, the

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force acting on the unit N pole must be the same just outside as just inside the circle ABD. But if there are B lines of force per square centimeter at E in the outer (magnetic) medium, the force per unit pole is equal to (B/μ) (TECHNICS, Vol. II., No. 12, page 575). If there are H lines of force per square centimeter at G in the inner (non-magnetic) medium, the force per unit pole is equal to H. Hence,

$$\frac{B}{\mu} = H,$$

or

$$B = \mu H.$$

From this we conclude that *at any point in the magnetic medium, there will be μ times as many lines of force per square centimeter as if the medium were non-magnetic.* The force acting on a unit N pole is, however, independent of the nature of the medium; we may suppose the magnetic medium to reach right up to the conductor, and the force acting on a unit N pole at any point will remain exactly the same as if this medium were absent. Thus the force exerted by a current on a pole is independent of the surrounding medium, and consequently, the force exerted by the pole on the current is independent of the nature of the surrounding medium. As the number of lines of force leaving a given pole is independent of the medium (TECHNICS, Vol. II., No. 12, page 575), we conclude that the force acting on the current depends only on B, the number of lines of force per square centimeter due to the independent field in which the conductor is placed, the current C, and the length l of the conductor.

Consider the case of two long parallel wires, each carrying a current equal to C, the surrounding medium having a permeability equal to μ, the distance between the wires being equal to r. At a distance r from a long conductor carrying a current C, the force per unit N pole is equal to $2C/r$ whatever may be the nature of the surrounding medium; and since the number of lines of force per square centimeter is equal to μ times the force per unit N pole, either conductor is placed in a field B equal to $2\mu C/r$ lines of force per square centimeter due to the other current. Then, since the force acting on the conductor is equal to BlC, where l is the length of the conductor, it follows that this force is equal to—

$$\frac{2\mu C}{r} lC = \frac{2\mu l}{r} C^2$$

Thus the force between two given currents at a given distance apart is directly proportional to the permeability of the surrounding medium. On the other hand, as we have already proved, the force between a given current and a given pole at a given distance apart is independent of the permeability of the surrounding medium; while the force between two given poles at a given distance apart is inversely proportional to the permeability of the surrounding medium.

A further application of the principles discussed in the present article must now be considered, on account of its practical importance. Fig. 9 represents a ring comprising (1) a portion of large sectional area a_1 and mean length l_1, composed of iron of permeability μ_1; (2) a portion of smaller sectional area a_2 and length l_2, composed of iron of permeability μ_2; and (3) a narrow gap

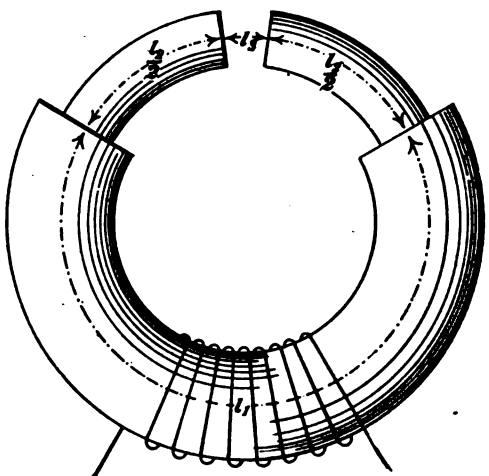

FIG. 9.—TO EXPLAIN THE NATURE OF THE MAGNETIC CIRCUIT.

(termed the air gap) between the free ends of the two narrower portions of the iron ring. Let a current C, in c.g.s. units, flow through n turns embracing the iron core; then if a unit N pole is taken round a closed curve through these n turns, the work done will be equal to $4\pi Cn$. Let B_1 be the number of lines of force per unit area in the portions of the iron ring with sectional area a_1; then the work done in carrying a unit N pole along the length l_1 of the axis of this portion will be equal to $(B_1/\mu_1)\,l_1$. If B_2 is the number of lines of force per square centimeter in the narrower portion of the iron ring, then the work done in carrying a unit N pole along the length l_2 of this part of the iron ring will be equal to $(B_2/\mu_2)l_2$. Let B_3 be the number of lines of force per square centimeter along the axis of the air gap; then the work done in carrying a unit N pole

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across the air gap will be equal to $B_3 l_3$, since for air $\mu = 1$. Then

$$4\pi Cn = \frac{B_1 l_1}{\mu_1} + \frac{B_2 l_2}{\mu_2} + B_3 l_3 \quad . \quad . \quad (1)$$

To a first approximation, the total number of lines of force passing through the thicker portion of the iron ring will also pass through the thinner portion; if this total number of lines of force is equal to ϕ, then $B_1 = \phi/a_1$, and $B_2 = \phi/a_2$. If the air gap is very narrow in comparison with the area of the free polar surfaces bounding it, we may assume that practically all the lines of force leaving one polar surface go directly across to the other, so that the ϕ lines leaving one polar surface and entering the other lie within an area of a_2 square centimeters in the air gap; then $B_3 = \phi/a_2$. Substituting in (1) above, we have

$$4\pi Cn = \phi \left\{ \frac{l_1}{\mu_1 a_1} + \frac{l_2}{\mu_2 a_2} + \frac{l_3}{a_3} \right\} \quad . \quad . \quad (2)$$

From (2) it is seen that if we know C and n, together with the dimensions of the iron ring and air gap, we can find the value of ϕ, the total number of lines of force crossing the air gap; while if ϕ and the dimensions of the ring are given, we can readily calculate the value* of Cn necessary to produce the given value of ϕ. It must here be remarked that for magnetising forces greater than about one-tenth of the earth's horizontal component, μ is not constant, but depends on the value of B. The magnetisation curve for a given sample of iron may be plotted by obtaining the value of B_1, the number of lines per square centimeter in a sample of the iron, for different values of H_1, the magnetising force (force per unit pole) within the iron; then for a given value of B_1 in (1), we have $B_1/\mu_1 = H_1$, where H_1 is the magnetising force corresponding to the given value B_1 on the curve. The same method can be applied to find B_2/μ_2, if a magnetisation curve for a sample of the corresponding iron has been obtained. The name of the late Dr. John Hopkinson will always be associated with this method, which, more perhaps than any other development of electrical science, has contributed to the success at present attained in the design of dynamos and motors.

A similarity between the above results and those appertaining to the electric circuit must now be mentioned. If E is the E.M.F. in a circuit, consisting of conductors with resistances R_1, R_2, R_3, arranged in series, then the current C is given by the equation

$$E = C(R_1 + R_2 + R_3) \quad . \quad . \quad (3)$$

Now if the conductor of resistance R_1 is composed of a substance of resistivity r_1, the length and sectional area of the conductor being denoted by l_1 and a_1, then

$$R_1 = r_1 \frac{l_1}{a_1}$$

Similarly, we may write

$$R_2 = r_2 \frac{l_2}{a_2}, \text{ and } R_3 = r_3 \frac{l_3}{a_3}$$

Then

$$E = C\left(r_1 \frac{l_1}{a_1} + r_2 \frac{l_2}{a_2} + r_3 \frac{l_3}{a_3} \right) \quad . \quad (4)$$

There is an obvious similarity between equations (2) and (4). In the electric circuit, given the value of the E.M.F. and the total resistance of the circuit, we can readily calculate the value of the current C; or if the E.M.F. and current are given, the value of E/C gives us the total resistance of the circuit. In the magnetic circuit, the value of $(4\pi C n)/\phi$ gives us the magnitude of the quantity within the brackets on the right-hand side of (2), which is termed the *magnetic resistance* or *reluctance* of the circuit; so that $4\pi C n$ and ϕ in the magnetic circuit respectively correspond to E and C in the electric circuit. The quantity $4\pi C n$ is very generally known as the *magnetomotive force* (M.M.F) of the magnetic circuit; this is a misleading title, since it does not refer to the force per unit N pole at any point of the circuit, but the work done in carrying a unit N pole right round the magnetic circuit; a better, but somewhat cumbersome, name for $4\pi C n$ would be the *magnetic potential difference* (M.P.D.) round the magnetic circuit. It has further been suggested that, just as we may speak of the fall of electric potential round the electric circuit as the *voltage*, so we may speak of the fall of magnetic potential round the magnetic circuit as the *gaussage*.* The quantity ϕ, representing the total number of lines of force passing through any cross section of the magnetic circuit, is generally known as the *flux*. Thus in the magnetic circuit we have

$$\frac{\text{Gaussage}}{\text{Flux}} = \text{Reluctance},$$

just as, in the electric circuit, we have

$$\frac{\text{Voltage}}{\text{Current}} = \text{Resistance}.$$

* Cn is of course equal to one-tenth of the product of the current in amperes into the number of turns; or one-tenth of the *ampere-turns*.

* In honour of Gauss, a celebrated German physicist; gaussage is pronounced *gouce-age*.

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There is, however, an important difference between reluctance and resistance which must be noted. By Ohm's law, when the temperature of the conductors in the electric circuit remains constant, the value of the ratio *voltage/current*, or the resistance, remains constant, whatever may be the value of the current. In the magnetic circuit, the value of the permeability varies with the flux density (number of lines of force per square centimeter) and therefore with the flux ϕ, so that the reluctance of the magnetic circuit will vary with ϕ, unless there is no iron, steel, nickel, or other magnetic substance in the circuit.

Comparing equations (2) and (4), it is easily seen that r, the *resistivity* or specific resistance (*i.e.*, the electrical resistance between opposite faces of a centimeter cube of the substance of which the conductor is composed), corresponds to $1/\mu$, the reciprocal of the permeability. Thus $1/\mu$ is termed the *reluctivity* of the portion of the magnetic circuit. Mr. Heaviside has suggested that μ should be called the *permittivity* (instead of the permeability), in order to bring it into line with the term *conductivity* applied to the corresponding quantity in the electric circuit.

(*To be continued.*)

CUTTING, GRINDING, AND MOUNTING ROCK SECTIONS.

By E. HOWARD ADYE.

ALTHOUGH many of the current handbooks of microscopy, geology, and petrography contain more or less explicit directions for the preparation of thin sections of minerals and rocks for microscopic examination, none of them explains how the task ought to be performed, from commencement to finish, in a thoroughly workmanlike way. It is far from satisfactory to only occasionally succeed in securing sections sufficiently thin for scientific research, but this is all that can be expected from the methods usually indicated; whereas, by carrying out the following instructions in their integrity, the careful operator can scarcely fail to obtain results, not only eminently suitable for research, but worthy of preservation as works of art.

Rocks vary very considerably in their textures, from blown-sand and soft clays, through friable chalks, to such indurated substances as granite, basalt, marble and the like. It is only with the latter types of coherent and hard rocks that the author proposes to deal. Valuable hints on the collection and treatment of suitable rocks are recorded by Rutley.* To minimise the labour of grinding, rock-chips for section-making should be procured as flat as possible on both surfaces, and ought to measure about one inch in diameter, and not more than one-eighth of an inch in thickness. With comparatively soft yet coherent rocks, such as most serpentines and marbles, the one-eighth of an inch can be rapidly reduced; but with hard rocks like basalts and granites, if the chip is much thicker than this the grinding by hand will be found very laborious.

The precise methods of preparation may now be considered under the following heads: — (I.) Procuring Chips or Slices; (II.) Grinding the First Surface; (III.) Cementing and Reducing the Slice; (IV.) Mounting the Section.

I.—Procuring Chips or Slices.

Suitable chips can best be obtained in the field by plying the square end of the geological hammer against advantageous edges of the rock. It will very soon be found that while some specimens can be procured with the utmost ease, others offer almost insurmountable difficulties; for example, the basalt of the Giant's Causeway will readily yield flake after flake of over one inch square, tolerably flat, and even less than one-sixteenth of an inch in thickness; while the utmost dexterity may be exercised in vain to procure a much smaller chip, one-eighth of an inch thick, from the granite of Shap Fells, or almost any other holocrystalline rock. In the laboratory, Mr. Rutley's directions* may be followed with advantage.

Apart from coarsely crystalline (granites,

* "The Study of Rocks." By Frank Rutley, F.G.S., etc. Longman's Text-books of Science, London, 1879, pp. 39–44, 59 *et sequentes*.

* *Loco citato*, page 60.

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etc.), and heterogeneous fragmentary rocks (breccias, etc.), there are numerous minerals and cleavable rocks which require to be cut in certain definite directions, or in planes other than those of their cleavage. In such cases it is imperative that the material shall be sliced. Some fairly compact rocks, such as hard chalks, limestones, serpentines, and even picrites and other volcanic rocks, can be easily sliced by hand, with the aid of a finely tempered tenon-saw lubricated with water; others, such as the harder dolerites, basalts, marbles, slates and the like, are also amenable to hand-slicing by means of a toothless soft-

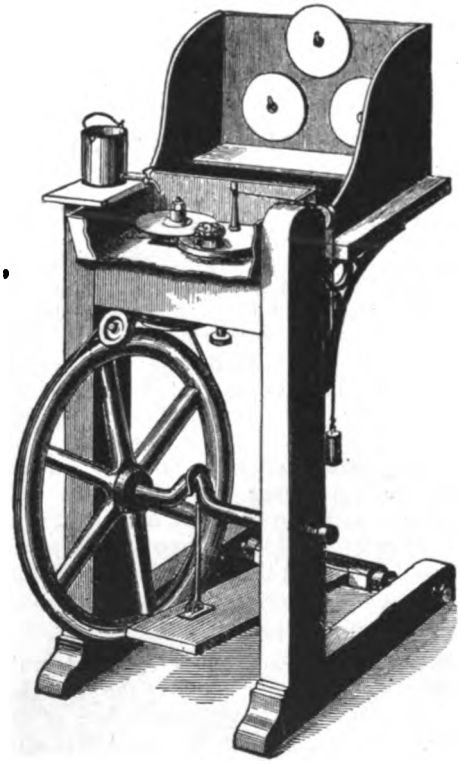

FIG. 1.—JORDAN'S LAPIDARY BENCH.

iron tenon-saw plentifully supplied with water and an abrasive powder, such as No. 90 hole* emery, or, better still, the wonderful new material known as "carborundum" powder, of about the same calibre.

Carborundum is the name given by Mr. E. G. Acheson, of Niagara Falls, N.Y., U.S.A., to an artificial silicide of carbon, having the formula CSi, which has not hitherto been found in Nature. It is formed by fusing a mixture of coke and sand, with salt as a flux, in an electric furnace. It crystallises in the hexagonal system, and possesses abrasive properties superior even to those of sapphire. While not quite so tough as diamond bort, it approaches the hardness of this substance.

Hand-slicing is, at best, a laborious process, so that the assistance of a working lapidary is often requisitioned. Every modern well-equipped laboratory, however, ought to be provided with a good lapidary bench for both slicing and grinding minerals and rocks for microscopic observation. Many such machines are made by German laboratory fitters; but there is to-day only one thoroughly trustworthy appliance of the kind in the English market. This excellent "Amateur's Lapidary Machine"

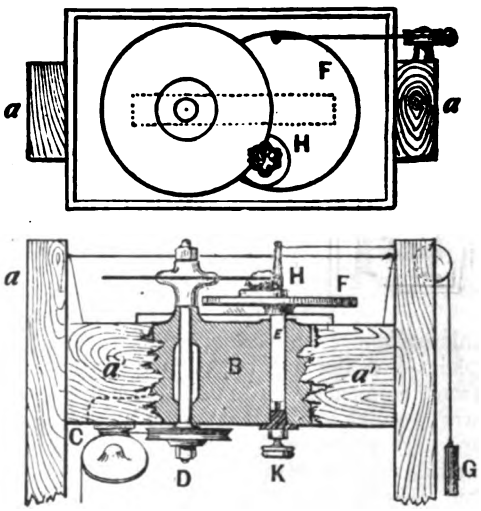

FIG. 2.—PLAN AND SECTION OF JORDAN'S LAPIDARY BENCH.

was devised by Mr. James B. Jordan, of the *Mining Record* office, and is made and supplied by Messrs. Cotton and Johnson, of 14, Gerrard Street, Soho, London, W.

The working parts of Jordan's Lapidary Machine are clearly shown in Figs. 1 and 2. From these it will be seen that the appliance consists of a strong framework of seasoned mahogany, the pillars of which (*a*, *a*, Fig. 2) support a heavy crank-axle worked by the treadle, and a driving wheel two feet in diameter, much as in an ordinary turning-lathe. The upper portion of the frame is bound by two cross-pieces *a'*, fixed about an inch apart, to form the bed of the lathe. Between the cross-pieces is placed an iron casting B, which is bored to receive the spindle D,—the upper free end of which is fitted with

* The term "No. 90 hole" means, that the grains of the powdered material have been passed through a sieve having ninety threads to an inch, but will not pass through one with 100 threads to the inch.

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brass clamps between which the slitting disc or grinding wheel (lap), is firmly secured by the nut above. The lower end of the spindle carries a small horizontal driving-wheel; a bracket C supports a pair of angle-pulleys, so that the thong from the treadle fly-wheel is made to traverse the angle-pulleys and thence around the small driving-wheel of the spindle D. By this means, when the treadle is worked, motion is communicated to the driving-wheel attached to the spindle D, which rotates the slitting-disc or lap at the rate of from 400 to 500 revolutions per minute. The casting B is also bored to receive a second spindle at E, to the top of which is fixed a circular gun-metal plate F, for carrying a small saucer H, into which the specimen to be sliced is cemented. The plate F can be raised or lowered by means of the thumb-screw K; this adjustment provides for the regulation of the thickness of the slice to be cut. To the brass plate F, a piece of strong string or catgut is attached; this hangs over a pulley, fixed outside the framework of the machine, and supports the weight G, which consists of a brass cylindrical box containing lead shot, so that it can be lightened at pleasure to accommodate itself to the requirements of the specimen operated upon. This simple contrivance ensures a constant pressure of the specimen against the cutting-edge of the slitting-disc; and, when the latter is put into motion, the specimen is kept firmly held in position, until it has been sliced through. The plate F may then be revolved backward, and the specimen elevated to any desired degree by means of the thumb-screw K, and a second cut taken. It may occasionally, however, be advisable to steady the work *by hand, and not to depend entirely upon the automatic pressure afforded by the counterpoise* G.

Slices of minerals and rocks for microscopical slides ought to range from about one-sixteenth to one-eighth of an inch in thickness. The slitting-disc at the upper end of the spindle D (Fig. 2) is made of soft iron or softened steel, and is slightly convex on its upper surface. It is about eight inches in diameter and about one-fiftieth of an inch in thickness. The edge of the disc should be turned true, at right angles to its surfaces, and then carefully primed with a powder of exceptional hardness. For this purpose, carborundum "flour" of the water-grades "FF," or "FFF," may be used for slicing specimens which reach up to about No. 6 of Mohs's scale of hardness, such as bones and teeth, most fossils, calc-spar, fluor-spar, apatite, felspar, and limestones, marbles, indurated chalks, serpentines, picrites, dolerites, basalts and even diabases. Minerals ranging from No. 7 and more, such as quartz, garnet, topaz, corundum and the majority of the acid rocks (*i.e.*, pitchstones, granites, sandstones, quartzites, eclogites, and so forth) although capable of being cut by carborundum, are apt to prove too troublesome, and therefore call for something harder, such as diamond dust, for charging the edge of the slitting disc. As diamond dust is expensive, and when purchased ready-made is often adulterated, it is safer to buy diamond bort from some well-known mineralogist, and to subsequently pulverise it.* To do this successfully without fear of waste, a diamond-crushing mortar will be found indispensable. This useful accessory is shown in perspective and sectional views in Fig. 3 to indicate its shape. It is fashioned from hardened steel. The diamond bort should be reduced to powder so fine that no sparkling is revealed by diffused daylight.

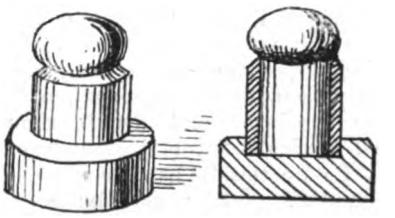

FIG. 3.—DIAMOND-CRUSHING MORTAR.

To prime the disc-edge, either flour carborundum or diamond dust may be used, according to circumstances. A few grains of the abrasive should be placed in a watch-glass or artist's saucer-palette, and made into a paste with a drop or two of olive oil. A particle of this paste should then be taken up with a quill and applied, inch by inch, to the edge of the slowly revolving disc, until the whole circumference has been charged. Care is then required in order to gently rub the particles well into the substance of the disc-edge by means of the glass or steel roller provided for that purpose (Fig. 4).

FIG. 4.—ROLLER FOR CHARGING EDGE OF DISC WITH ABRASIVE POWDER.

Particular care must be taken to avoid smearing the *surfaces* of the disc with the abrasive paste, as this would not only be

* Diamond bort is valued at about 10*s.* 6*d.* per carat.

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wasteful, but destructive alike to disc and specimen. The work must be kept constantly lubricated, preferably with oil-of-brick (spirits of turpentine or soap and water will do), by means of a drip-tap from a lubricating bottle or can, as shown in the perspective drawing (Fig. 1), which also shows a tray surrounding the working parts, to collect the waste which flies off the disc or lap during its revolution, and serves at the same time to protect the spindle bearings from dirt and grit. This contrivance can, with care, maintain the work in such cleanliness as to permit the operator to give demonstrations on the machine, if need be, even in a library or drawing-room.

II.—Grinding the First Surface.

Whether with chip or slice, the operations of grinding the first surface by hand or machine power remain essentially the same. The specimen, held firmly between the tips of the forefinger and thumb, should be rubbed perfectly flat and smooth on one side. To do this by hand, either emery or carborundum powder may be used, with plenty of water, on a well-flatted zinc plate, measuring about eight by ten inches superficially, and one-quarter of an inch thick. These dimensions have been found by experience to be the most generally useful. A coarse abrasive (No. 70 or No. 90 hole emery or carborundum, according to the nature and texture of the rock) should be employed for the initial grinding, which must be continued until an absolutely flat face of the desired dimensions—say one inch in diameter—has been obtained. The chip or slice should be rubbed (with moderate pressure, and care to keep the tips of the fingers clear of the grinding surfaces), round and round in circles, commencing at the top left-hand quarter of the plate, and then proceeding gradually to the lower left, the lower right, and the upper right-hand quarter, to finish off with a series of concentric movements around the centre of the plate. This procedure will prevent the zinc-plate surface from wearing into hollows and ridges, and so producing irregularities in the ground surface of the specimen. The operator will, of course, learn by practice the necessity for a sufficient supply of water and replenishment of the abrasive powder from time to time. The specimen must next be washed thoroughly free from adhering particles, and the operation of grinding repeated on a second zinc plate of like dimensions, with flour emery or "FF" carborundum powder. Its surface ought then to be quite flat and fairly smooth. If examined with an ordinary magnifying glass, however, sundry scratches will be discerned, and these should, after careful washing, be eliminated by briskly rubbing the surface of the specimen forwards and backwards on the prepared top of a water-of-Ayr stone, or an extra fine "hand-washed powder" carborundum hone. Precautions should be taken, however, to ensure the maintenance of a slightly convex surface on the water-of-Ayr stone, otherwise the surface of the slice or chip will tend to depart from the desired "dead level," and the resulting section, when completed, will inevitably be thicker towards the centre than at the edges. Scientifically considered, such a section is of greater value to the student of lithology than preparations that are uniformly cut, unless more than one is available; but, commercially, they are accounted inferior by dealers, as betraying bad workmanship. An absolutely flat or "dead-level" surface, free from scratches, when examined with an ordinary hand lens or magnifying glass, ought to be secured after sufficient rubbing on the water-of-Ayr stone; for which, of course, similar stones, such as Turkey, Washita, Arkansas and others, or the exquisitely fine-grained varieties of compressed carborundum oil stones and tool or razor sharpeners may be substituted. It is unnecessary to develop a polish upon the surface with putty-powder or jeweller's rouge, as all microscopic scratches practically disappear by the method of mounting the finished section in Canada balsam.

III.—Cementing and Reducing the Slice.

The requisites for cementing the first surface of the chips or slices, developed as directed above, are:—(1) A suitable cement. (2) A piece of plate-glass, one-quarter inch thick, cut into squares of about 1·5 inches, with the edges smoothed by a file, or, better still, upon a piece of compressed carborundum, or on a zinc plate with a little No. 90 hole emery or carborundum, so as to avoid the risk of cutting one's fingers during the subsequent processes of grinding and finishing. (3) A Bunsen burner, spirit-lamp, or small ordinary paraffin lamp with chimney. (4) A tripod or other iron stand with hot-plate, usually made of copper, although an ordinary piece of tin-plate (such as the top of a biscuit-box) will do. (5) Cork-tipped forceps.

Suitable Cements.—It will be remembered that in dealing with Jordan's Lapidary Machine, instructions were given for the use

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of a cement wherewith to fasten the hand-specimen of rock to be sliced on to the detachable saucer H (Fig. 2), on the circular brass plate F. Such cement may be purchased ready-made from oilmen, drysalters and other dealers, under the name of Waller's wax or red cement; but, as many students like to know how to make their own materials, the following recipes are given, and may be relied upon implicitly.

(*a*) Take Burgundy pitch, resin and beeswax. The precise proportions are not important, because samples vary very considerably, and the mixture is liable to be affected by seasonal or climatic changes. In summer more resin, and in cold weather more pitch and beeswax, should be used. The ingredients are to be melted together and thoroughly incorporated in a sand or water bath, and then formed into lumps or sticks for future use when wanted; the requisite quantity should be melted off into the supporting saucer (previously warmed), and the mineral or rock, also well warmed, can then be embedded in the wax in the desired position; in about half-an-hour, the wax will be found to be quite solid, and to hold the specimen securely in position. This cement has the advantage of being very tenacious and cheap. Its specific use is for cementing specimens in bulk during the process of slitting. It cannot, however, be recommended for fastening the smooth surfaces of slices on to the squares of plate-glass for reduction by grinding; for this purpose, as well as for cementing hand specimens for slitting, the author has been in the habit of using a shellac cement, which, when properly made and applied, will fasten the specimen to the base with perfect security.

(*b*) The formula for the author's shellac cement runs as follows:—Melt some Venetian turpentine (about three ounces will be sufficient), and strain it through fine muslin (placed filter-paper-wise in a hot-water funnel) into an evaporating dish, to be afterwards placed with great care over a small Bunsen flame or other source of heat.* When quite mobile add flakes of commercial orange shellac freed from dust and dirt. Stir about with a glass rod until thoroughly incorporated, and test from time to time by removing a small portion at the end of the rod. When the sample solidifies into a hard and glassy bead, it may be considered ready for use. As a confirmatory test, a chip of rock previously heated should be fastened on to a piece of warmed glass and allowed to cool. If the cement does not set hard and glassy in about a couple of minutes or so, but exhibits a greasy appearance, more shellac must be added to the mixture, until the desired result has been attained. When ready, pour a small quantity of the hot cement upon a cold (damped) slab of marble, or dinner plate, and roll or squeeze it with the fingers into a lump about the size of a walnut or filbert. Continue this process until all the material has been collected, when the evaporating basin should immediately be reheated, wiped out, and finally cleansed with a rag dipped in methylated spirit.* For the sake of convenience, these lumps of cement may be rolled or moulded into sticks like sealing-wax, by being immersed in very hot water, and, when sufficiently softened, rolled out by hand upon a plate of glass, or pressed into moulds of any desired shape.

Professor Rosenbusch (*Mikroskopische Physiographie der massigen Gesteine*), strongly recommends a mixture made by amalgamating, by heat, sixteen parts by weight of Canada balsam and fifty parts of shellac; but this cement, though equally tough and useful for grinding very thin sections, does not mix quite so readily or dissolve quite so freely in methylated spirit as the above, besides which, Venetian turpentine is cheaper than Canada balsam.

Having prepared the cement as directed, in the form of a stick of sealing-wax, a portion of this should next be melted on to the surface of one or more of the small one-and-a-half inch squares of plate-glass, by heating the latter on a hot plate of metal, over a Bunsen or other flame. The smooth surface of the specimen (slice or chip) ought to be warmed over the flame to dispel any moisture, and placed, face downwards, in the melted cement. The heated plate of glass supporting the specimen should then be removed, by means of a pair of cork-tipped forceps, on to a smooth pad of paper (a blotting-pad will do) on the adjoining work-table, where the specimen, now cooling, should be firmly pressed down, with a slight screwing motion, on to the plate of glass, using the thumb and fore-finger guarded by a glove, so as to squeeze all superfluous

* To prevent accidents, as the turpentine is very inflammable.

* The author finds that, to succeed in this kind of technical work, it is absolutely necessary to keep utensils and instruments perfectly clean, and to clean them thoroughly as soon as done with.

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cement to the borders of the chip or slice, and exclude air-bubbles. By this time, the small plate of glass will have cooled down sufficiently to enable the operator to take it up in the fingers of a gloved hand, when the adherent surface may be carefully examined to see that it is quite free from included air. If air bubbles are present, the reflection of light from them will plainly indicate this; in that event the plate of glass must be re-heated, and the entire operation repeated, until a successful result has been secured; otherwise, the specimen will almost surely be destroyed during the final stages of grinding. After a little practice, however, specimens can be cemented in quick succession without fear of failure, while the operation of repeating the process, in case of the presence of air-bubbles, is not by any means so troublesome or annoying in practice as it appears to be in print. Cork-tipped tongs or forceps may be easily improvised from a pair of old compasses, into the ends of which the separate halves of a sound bottle-cork, cut lengthwise into two, may be inserted (Fig. 5).

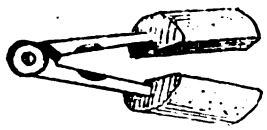

FIG. 5.—CORK-TIPPED FORCEPS.

When quite cold, the chip or slice of rock, safely cemented to the small square of plate-glass, ought to be surrounded by an appreciable margin of the squeezed out cement. This serves to protect the edges of the specimen from wearing away prematurely during the subsequent process of grinding. As the plate-glass square is intended to serve as a handle to the specimen, it will be readily understood that it ought not to be less than a quarter of an inch thick, so as to afford sufficient grip for the fingers while the slice is being reduced by grinding. It may here be mentioned that students who do not possess a lapidary machine to work with, would do well to purchase a few broken carborundum wheels, flat on both surfaces, for the rough and fine grinding operations, instead of using emery or carborundum powders on metal or glass plates. Pieces of broken wheels, approximating to No. 60 and No. 90, may be used in place of No. 90 and flour carborundum respectively; and it will be found that, apart from enhanced cleanliness, the work of reduction can be effected more rapidly. All that has to be done is to rub the specimen with a liberal supply of water on the vitrified solid carborundum. These vitrified wheels can, of course, be adapted to the lapidary machine in place of lead, zinc or other laps. The essentials to be remembered at this stage of the work are, that the specimens should be washed (even brushed with a nail-brush) perfectly free from one grade of powder before being subjected to grinding with a finer grade; and that the chip or slice, now assuming the character of a section, should be frequently examined. No hard-and-fast rules can be given as to the exact method of procedure; but the following hints will doubtless be found useful:—Press the cemented specimen, face downwards, on to the grinding surface firmly between the fore-finger and thumb, with care to keep the tips of the fingers free of the grinding slab or wheel—the quarter-inch of thickness of the square plate-glass holder will now be duly appreciated. Proceed with the first rough grinding, using No. 90 carborundum powder, or its equivalent vitrified wheel, till the section (as it must henceforth be called) becomes translucent. These directions must be followed with discretion; *e.g.*, a quarter-inch slice of clear quartz would be transparent, but a slice of any tough volcanic rock would need to be cut to about one-hundredth of an inch or less, before becoming even faintly translucent. Then again, such rocks as shales and limestones are not generally capable of withstanding the coarse grinding till they become translucent; while other hard and vitreous rocks, such as some pitchstones, rhyolites, phonolites, and the like admit of being reduced to great tenuity, even with very coarse abrasives. Judgment gained by experience will, however, serve to indicate exactly when the coarse grinding of any particular specimen should cease. After careful washing, the section must be still further reduced by the process of fine grinding on a separate plate or lap charged with flour emery or flour "FF" carborundum, until, as a rule, the bars of a window or other bold external object can be just barely detected through its substance. A second thorough washing now becomes necessary, and the section should be examined under a low power of the microscope (say twenty diameters). It should then be finally rubbed down, with frequent washings and peeps through the microscope, until it is judged to be sufficiently thin. A crude test may be applied to ascertain if the section is thin enough for general study, by placing the plate of glass and section over fairly small type

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such as "minion," "nonpareil," "ruby" or "pearl." If the type can be deciphered through a dark basalt, dolerite, picrite or limestone, the section may be considered sufficiently thin; but the only sure test, or series of tests with ordinary and polarised light, must, of course, be conducted through varying powers of the microscope, from 20 to 150 diameters, or more. It may be added that thickish sections sometimes teach what cannot be gathered from those of excessive tenuity, and *vice versâ*. For instance, when very thin, the "hour-glass" structure in certain augites cannot be detected without the polariscope. To give a better example, when the picritic-serpentine of Menheniot is cut moderately thin, it shows the crystals of much-fractured augite to perfection, but the true aggregate character of the secondary magnetite cannot be made out; whereas, if the section is cut so thin as to reveal the precise nature of the magnetite patches, the crystals of augite invariably disintegrate and drop out of the section altogether.

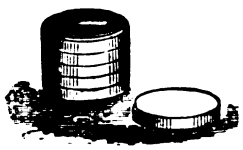

FIG. 6.
NEST OF SAUCERS.

To remove the section from the plate-glass, and free it from even the slightest trace of the cement, it should be turned face-downwards into a shallow saucerful of good methylated spirit and covered with a pane of glass; or better still, the nests of porcelain saucer-palettes, about four inches in diameter, as sold by most artists' colourmen, may profitably be utilised. The usual cabinet nest of saucers shown in Fig. 6 will hold five sections at a time, one in each saucer. Just sufficient methylated spirit should be poured into each saucer to come above the lower edges of the plate-glass square, and the whole nest may then be covered and set aside. It will be found that the sections become detached and sink to the bottoms of the saucers: some of them, more porous or loosely textured than others, may become detached in less than a couple of hours, others may take as many days; but *on no account must they be tampered with* by heating over a Bunsen or other flame and shifting off with a pen-knife, needle or other instrument; neither should the sections be washed with camel's-hair or any other kind of brush. These precautions are absolutely necessary. As soon as the sections become detached through the solvent reaction of the spirit, the squares of glass should be removed, and immediately wiped clean for future use. The discoloured spirit in the saucer can then be poured gently away from the section, and its place supplied by clean spirit. This operation should, if need be, be repeated three times, after which the sections will be found sufficiently free from undesirable impurities. The spirit finally should be drained away, leaving the sections intact in their respective saucers. In the course of a few minutes, especially in a warm, dry room, the small quantity of spirit left adhering to the sections will evaporate. Rectified benzol may now be added to just cover each section, and they will then be ready for mounting.

(To be continued.)

CHEMICAL NOTES.

A Delicate Test for Carbon Bisulphide

PLACE 10 cc. of the liquid to be examined in a test tube; cap the mouth with filter paper moistened with a strong solution of caustic potash in absolute alcohol, and heat gently to boiling; place the paper on a watch glass, and moisten with a few drops of a 5 per cent. solution of copper sulphate. The presence of carbon bisulphide, 1 : 2000, will be shown by the development of an intense yellow colour, due to the formation of copper-xanthogenate. (P. Bompard. Annales de Chim. Analyt. 9, 111.)

The Sensibility of the Organs of Smell

M. BERTHELOT concludes that the limit of sensibility of the organs of smell is about one billionth of a milligram. Some idea of the delicacy of this perception may be formed by considering the case of iodoform, which would appear to give off this amount of odour in a given volume of air per hour. In a year it would lose a little less than $\frac{1}{100}$ milligram, or one milligram in a hundred years. With musk the loss of weight would be materially — possibly a thousand times—less. (Comptes Rend. 138, 1249.)

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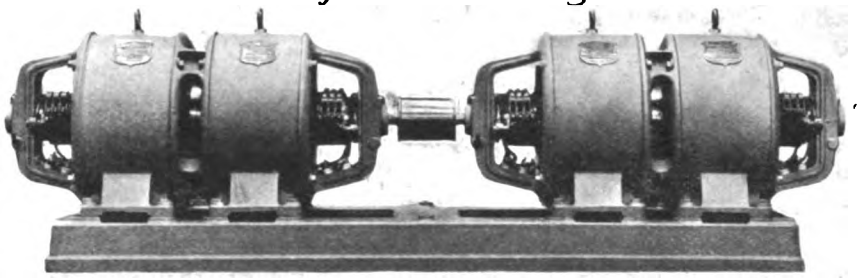
BOOSTERS.

By Harold H. Broughton.



A BOOSTER may be defined as an appliance which is used to add an E.M.F. to a circuit in which an E.M.F. already exists. The method of raising the voltage by means of an auxiliary machine was invented in 1881 by Professor J. Perry. Of late years boosters have been largely used in lighting and traction stations, and there are many excellent machines on the market; to describe them all would be difficult, so we must content ourselves with a description of one or two types representative of each class.

In order to avoid confusion we shall subdivide the subject into two sections:—(I.) Rotary boosters, and (II.) static boosters.

The boosters coming under (I.) are used in connection with direct current systems, and those coming under (II.) for alternating current systems.

Rotary Boosters.

Rotary boosters may be divided into two groups:—(1) feeder boosters; (2) battery boosters.

We shall consider each group in turn, noting the purposes for which they are intended, and the general construction.

Feeder Boosters.

The voltage drop in very long feeders is considerable, and under certain conditions it is more profitable to "boost" the pressure at the end of the line by means of a small generator, than to put down heavier cables. The elementary diagram of connections is shown in Fig. 1. The machine consists of a shunt motor M, supplied from the mains, mechanically coupled to a series dynamo B in circuit with the feeder. The advantage of this arrangement is that the voltage across the booster terminals is proportional to the current in the feeder. Some makers do away with the necessity of providing the driving motor M, by mounting the booster armature on the end of the shaft of one of the main generators G, but there are many drawbacks to this arrangement, and, in consequence, it is but little used.

The booster may also be shunt or compound wound, in which case the shunt winding is excited by means of a small series-wound exciter, as shown in Figs. 2 and 3.

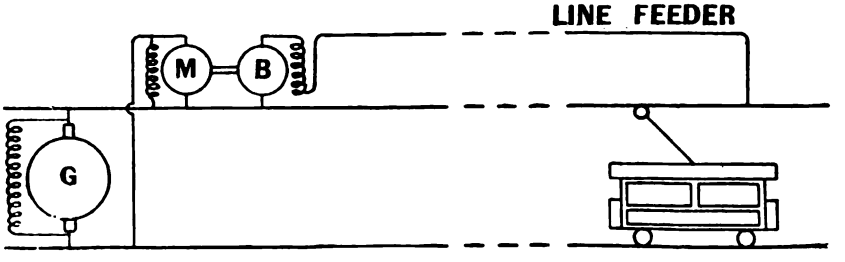


Fig. 1.—Positive Booster for Traction System.

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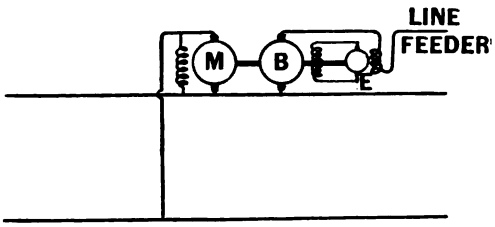

FIG. 2.—SHUNT WOUND BOOSTER.

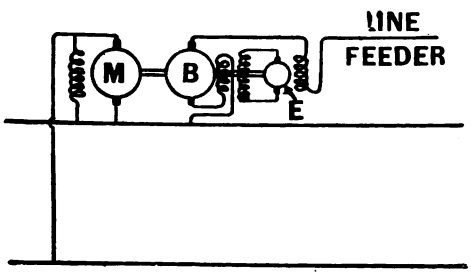

FIG. 3.—COMPOUND WOUND BOOSTER.

In connection with tramway systems, the fall of pressure in the uninsulated return must be less than seven volts in order to comply with the Board of Trade regulations; amongst other methods of ensuring this, may be mentioned the use of auxiliary return feeders with *return* or *negative boosters*.* The method was proposed ten years ago by Major Cardew, and independently by Kapp, and is used in many large tramway systems both at home and abroad. Fig. 4 shows the application of a booster to one of the return feeders of a tramway system. The negative 'bus bar N is connected permanently to the rails at T. The booster armature B is in series with the return feeder from a distant point D of the track, and the field F is connected in series with the line feeder. The booster is driven at constant speed by a motor, and gives a pressure practically in direct proportion to the current in the line, and, therefore, to the current in the feeder also. The fall of pressure, which is directly proportional to the current flowing in the return feeder, can thus be almost exactly counterbalanced by the booster. The results in practice are most satisfactory; it has been found that the machine works automatically, and the voltage drop in the return feeder may be limited to any desired amount by adjusting a rheostat in parallel with the field coil. In some systems there are several return feeders, each with its own booster and its corresponding line feeder; in such cases it is often convenient to couple the whole of the boosters mechanically with one motor for driving. Rider* states, that several instances have occurred where negative boosters have proved useless, owing to the booster field being connected in series with the return feeder, instead of with the line feeder. The reason for this is as follows:—Since the negative 'bus bar is connected to the track at the generating station, the booster will be working as a series dynamo on a closed circuit consisting of the rails and return feeder, and the current flowing will depend entirely upon the resistance of this circuit and the characteristic of the dynamo. It is usually found that sufficient current will continually flow round this circuit to entirely upset any self-regulating properties of the booster.

As an example of the use of this system we shall describe the boosters used in the Bristol Tramways Power Station designed by Mr. H. F. Parshall,† and supplied by the British Thomson-Houston Company. Each of the three motor generators consists

* Proceedings of the Institute of Electrical Engineers. Vol. XXVII., page 446, 1898.

* "Electrical Traction," by Rider, page 109, 1903.
† "Traction and Transmission," February 1902, page 111.

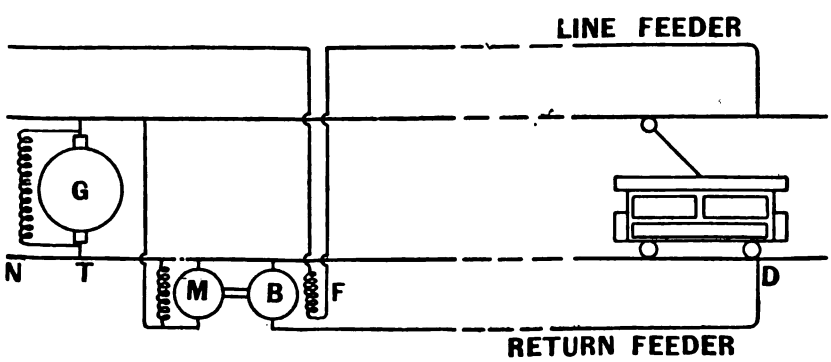

FIG. 4.—NEGATIVE BOOSTER FOR TRACTION SYSTEM.

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of two four-pole, continuous current, direct coupled machines, mounted on a single bedplate having three bearings. The combined efficiency of the motor generators at full load is 81 per cent. The generator is constructed as a series-wound machine, giving the characteristic shown in Fig. 5. The field of the generator is arranged so that it can be put in circuit with one or more of the positive feeders running to the trolley line from the positive 'bus bars at the switchboard in the generating station.

The armature is placed in circuit with the return feeder, one end of which is fixed to the negative 'bus bar, and the other end is

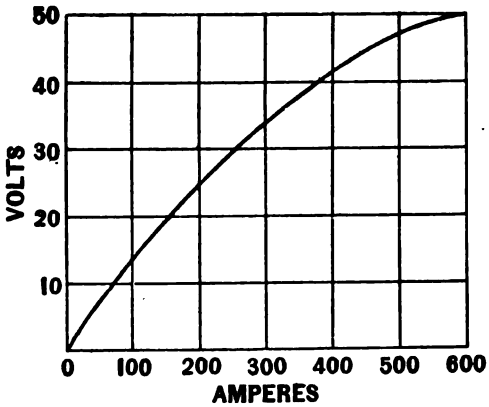

FIG. 5.—CHARACTERISTIC OF SERIES GENERATOR.

connected to the track rails at a distant point in the system. The generator is thus separately excited, and the current in the armature corresponds with the current in the field; when 600 amperes are passing through both the field and the armature, the machine will give 50 volts at the armature terminals. The insulation of the generator was tested by maintaining 2,500 volts (alternating) between the winding and the frame of the machine: further, the generator had to carry 600 amperes continuously without over-heating. The armature of the generator had to withstand a test of 1000 volts (alternating) between the winding and the armature core, and no part was to rise in temperature more than 40°C. above the surrounding atmosphere when generating 600 amperes at 50 volts. The commutator was designed so as to run sparklessly from no load to 25 per cent. overload without shifting the brushes. The field shunt of the generator is composed of four-point rheostats, each point having the following ratio as compared with the resistance of the field of the generator :—

Position No.	Continuous carrying capacity in Amperes.	Resistance of Rheostats Resistance of Field.
1	Off Stop.	∞
2	100	5
3	200	2
4	300	1

The motor driving this generator is a four-pole, 500 volt, shunt-wound machine, direct coupled to the generator, and capable of yielding a maximum output of 50 B.H.P. continuously. The commutator of this machine is so constructed that the average voltage between adjacent commutator bars does not exceed 10 volts when running at 550 volts. The motor can run continuously at full load without the temperature of the armature rising more than 45° C. above that of the surrounding atmosphere; the motor is free from sparking at all loads up to 25 per cent. over-load without moving the brushes. Three panels are provided on the switchboard: these have a maximum width of two feet, and each is provided with the following instruments suitable mounted thereon :—

(A) *Instruments in the motor circuit.*

One ammeter reading up to 100 amperes.
One 100 ampere quick-break switch.
One starting switch.
One magnetic blow-out circuit breaker, having a range of 75 to 150 amperes.

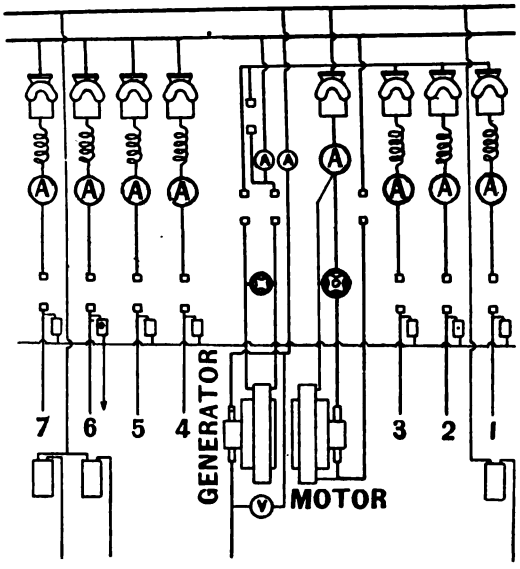

FIG. 6.—SWITCHBOARD AND CONNECTIONS.

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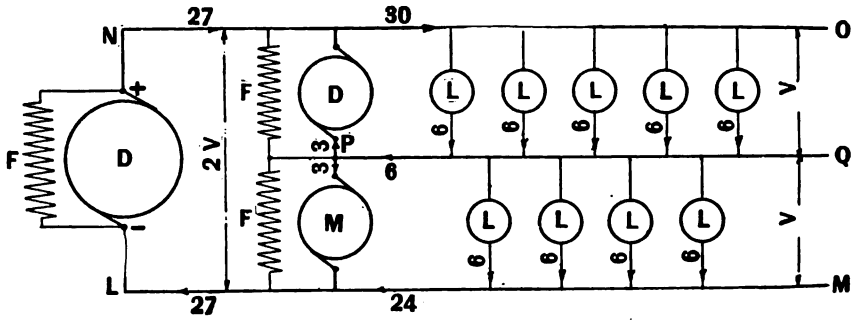

FIG. 7.—BALANCERS FOR THREE-WIRE SYSTEM.

(B) *Instruments in the generating circuit.*

Two ammeters, each reading up to 1000 amperes, arranged in the field and armature circuits respectively.

One voltmeter, reading up to 125 volts, in single volt divisions, with large dial.

Three quick-break switches, each of a carrying capacity of 100 amperes.

One four-point rheostat, as specified for motor generators.

A diagram of connections is given in Fig. 6, and from what has been said this will readily be understood.

Balancers.—In connection with three-wire systems, in order to take the "out-of-balance current" in the neutral wire when the two sections are unequally loaded, either two batteries, or a pair of machines coupled together electrically and mechanically, must be inserted at any convenient point in the system. These latter are known as *balancers*, and are in reality simple boosters.

When there is no current in the middle wire, the balancers will run as motors in series between the two outers; and since they are unloaded the current will only be that required to overcome the losses in the machines themselves, as the speed will be very high. However, the neutral wire nearly always carries current, as illustrated in Fig. 7. On the positive side there are five six-ampere circuits, and on the negative side four six-ampere circuits—*i.e.*, there is a current of six amperes in the middle wire. The resistance on the positive side is therefore four-fifths that of the negative side, and the P.D. between the negative and middle wires is five-fourths that on the positive side. Generally the voltage on the lightly loaded side tends to rise, and on the heavy side to drop by the same amount, and this difference brings the balancers into action, the function of these machines being to minimise the drop. The action is as follows:—Half the current in the neutral flows through the machine on the light side, causing it to run as a motor, driving the other machine as a dynamo, which will supply an equal amount of current to the heavy side.

The several methods of winding and connecting the fields are as follows:—*

1. Both machines may have plain shunt windings, the winding of each being connected directly across its own brushes with a regulating resistance in series (Fig. 8).

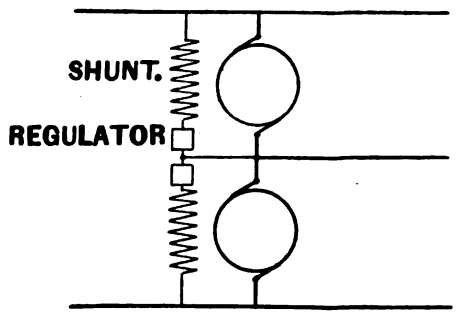

FIG. 8.—BALANCERS WITH PLAIN SHUNT WINDINGS AND REGULATING RESISTANCES.

2. The same arrangement as No. 1, except that the shunts are crossed, the winding of one machine being connected across the brushes of the other machine, and *vice versâ* (Fig. 9).

3. Both machines may be compounded (Fig. 10).

Of these three methods the second is probably the most commonly used at the present time, though the third method is in some respects superior to it, and is gradually coming into more general use.

As regards size and cost of machines, all three arrangements are alike, but the closeness

* See *Electrical Engineer* (London), April 24th, 1903, for a full discussion.

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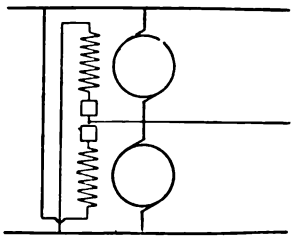

FIG. 9.
BALANCERS WITH CROSSED FIELD WINDINGS.

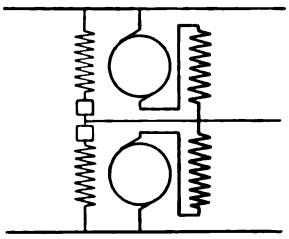

FIG. 10.
BALANCERS WITH COMPOUND WINDINGS.

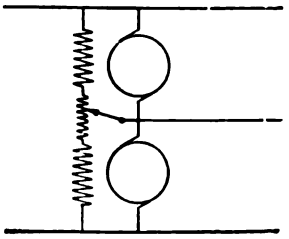

FIG. 11.—BALANCERS WITH A SINGLE REGULATOR CONTROLLING BOTH SHUNTS.

with which the voltages on the two sides are automatically kept equal depends considerably on the method employed. In (1), assuming that the shunts are adjusted so that the machines give the same voltage when both sides are equally loaded, then the difference in voltage on the two sides when the full out-of-balance current is passing is due to three causes:—

(*a*) The C R drop in both armature windings, which tends to make the motor run slow, and the dynamo give lower terminal volts when loaded.

(*b*) There is the armature reaction, which tends to raise the speed of the motor and lower the voltage of the dynamo, the two effects cancelling out more or less.

(*c*) There is a drop in excitation on the dynamo side, due to the drop in volts on the heavily loaded side.

The full load C R drop in the armature of a small machine cannot be kept below 2 per cent. without increasing the size unduly, so that from this cause the difference in volts between the two sides will be about 4 per cent. (assuming motor volts constant), and this will produce a further lowering of the dynamo volts of at least 2 per cent. This extra 2 per cent. drop will still further lower the dynamo excitation, and so on until a steady state is reached, with a total difference in voltage between the two sides of probably not less than 7 or 8 per cent. Actually, the one side would rise 3·5 or 4 per cent., and the other side fall 3·5 or 4 per cent. from the uniform no load voltage, the voltage across the outers being assumed to be constant.

With the arrangement (2) the drop due to resistance remains as before, but instead of a further drop due to the lowering of the excitation, there is an actual reduction of the C R drop; for, the motor shunt being now excited off the dynamo side, any drop on the latter side tends to increase the motor speed, and so raise the dynamo volts again. Taking the case of a 2 per cent. drop in each armature,

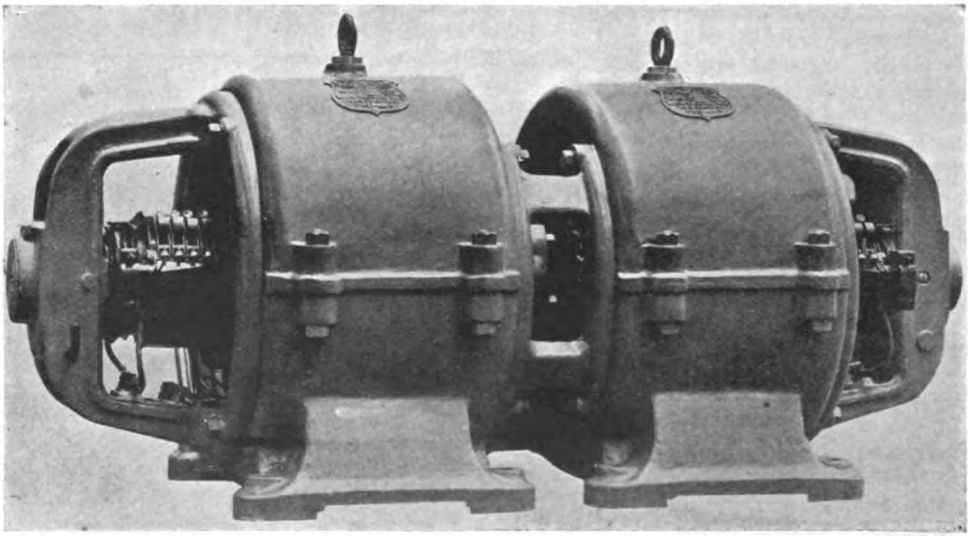

FIG. 12.—STANDARD BALANCER OF THE LANCASHIRE DYNAMO AND MOTOR COMPANY.

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the actual difference between the volts on the two sides of the system at full out-of-balance current would probably not exceed 3 per cent.

When a compound winding is used, as in (3), the drop can be reduced to zero, or can even be converted into an actual rise in voltage on the more heavily loaded side by suitably proportioning the series and shunt windings. The windings of both machines are connected up exactly as for compound dynamos, so that as soon as one machine begins to act as a motor, the series winding on it acts in opposition to the shunt winding, and this tends to help the compound winding on the dynamo machine to raise the volts on the heavily loaded side. In this way the combined action of the two series windings can either be made to keep constant volts on the two sides of the system, or to raise the volts on the more heavily loaded side, and so compensate for drop in the neutral. Whichever arrangement of the fields is employed, it is always advisable (and in the case of (1) and (2) necessary) to have a regulating resistance in the shunt windings, to enable the voltages on the two sides of the system to be controlled by hand when required. Very often a separate regulator is inserted in each shunt, but Fig. 11 shows an arrangement sometimes employed to enable a single regulator to control both shunts, the resistance cut out of one field being inserted into the other by the same operation, and so allowing the required change of voltage to be obtained by the motion of a single switch.

Fig. 12 shows a standard balancer by the Lancashire Dynamo and Motor Co. The illustration at the head of this article shows a balancer booster by the same firm; these latter machines are but little used, and as this discussion is already of much greater length than was originally intended, we had better pass on to the next section.

(*To be continued.*)

THE POWER OF PETROL MOTORS.

A CONVENIENT rule for finding the approximate horse-power of petrol motors is: "square the diameter of one cylinder in centimeters, and divide by five," for a four-cylinder motor; or, in other words, b.h.-p. of one cylinder = (diameter in centimeters)^2/20. For example, take an engine with four cylinders 100 millimeters bore, and 140 millimeters stroke, $10^2/5 = 20$ b.h.-p.—a very simple mental calculation which is just about correct, being based, of course, on assumed constant piston speed and volumetric efficiency. As a matter of fact, within limits, as the piston speed increases, the volumetric efficiency drops, so that an engine will give practically the same horse-power over a considerable range of speed, although the fuel economy will vary considerably. A glance at Fig. 1, which refers to an engine of the size mentioned, will show these points clearly. In the diagram, A shows the total b.h.-p. developed at the various speeds; B is the horse-power at unit speed, or, in other words, the b.h.-p. per revolution, multiplied by the normal revolutions (in this case 850), and shows the fall in volumetric efficiency; C shows the petrol consumption in terms of gallons per brake horse-power per hour. It will be noticed that, within 5 per cent. the horse-power developed is constant from 740 to 1130 revolutions per minute, but that in this range, the consumption increases from 0·09 to 0·13 gallons per horse-power hour due, mostly, to loss of volumetric efficiency and carburettor error.

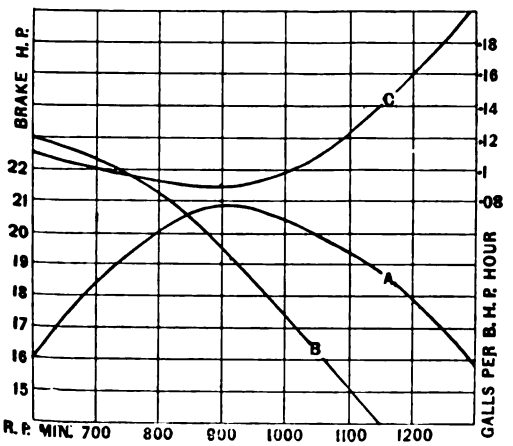

FIG. 1.—Curves showing connection between speed of petrol motor and (A) B.H.P.; (B) H.P. per revolution multiplied by normal revolutions; and (C) petrol consumption in gallons per B.H.P. hour.

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THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C.,
Chemical Engineer and Consulting Chemist, Manchester.

IN its simplest form, a still consists of a flask or retort into which the liquid to be evaporated is placed; this is connected with a Liebig condenser, from which the condensed distillate passes into a Woulfe bottle. If the latter is joined up to a Bunsen pump, the distillation may take place in a vacuum. It is well known that with diminished pressure the boiling-point of any liquid is considerably lowered, and that it is therefore possible to distill or evaporate liquids at a lower temperature in a partial vacuum than would be the case at ordinary pressure. In laboratory work this is chiefly done when the liquid which is to be evaporated would become partially or wholly decomposed if evaporated at its normal boiling-point. A solution of sugar, for instance, will partially decompose and become discoloured if evaporated under atmospheric pressure, whereas in a vacuum it yields pure white crystals. But whilst in the chemical laboratory the above is almost in all cases the only reason why evaporation in a vacuum is resorted to, it is found in practical work that even where one has to deal with stable substances, evaporation in a vacuum may offer advantages which counterbalance the extra outlay for apparatus, cost of condensing, and other incidental expenses.

We shall now attempt to evolve, from the laboratory apparatus which we have described, the simplest form of apparatus which might be used for technical purposes. We have first to consider how to transform the flask which holds the liquid, and, in the laboratory, would be heated by means of a water-bath or similar arrangement; this we can replace by any of the pot-shaped boiling down appliances which we have mentioned, particularly by a jacket pan, such as is shown in Fig. 12.* We should simply provide this pan with a lid, which, as it has to stand pressure, would be of hemispherical or similar shape, and would contain a pipe at the top for the purpose of carrying away the steam which is given off.

* TECHNICS, Vol. III., No. 13, p. 49.

In the laboratory apparatus, the steam evolved from the boiling liquid would be taken through a Liebig condenser; on a large scale the latter might be replaced by an upright pipe, which may be cooled from the outside by a stream of water trickling round its circumference; or the cooling water may be injected into the pipe by a spray arrangement, and mingling with the steam, condense it. The Bunsen pump which would be used in the laboratory arrangement would be replaced by a mechanical vacuum pump, of which there are two kinds. If constructed in such a way that it serves the purpose of keeping up a vacuum by drawing out the air only, it is termed a "dry" air pump; if it draws the condensed steam and condensing water as well, it is termed a "wet" vacuum pump. Fig. 13 shows such a simple arrangement, and represents the principles underlying the construction of vacuum apparatus. Alterations and additions naturally occur in improved working apparatus.

It is advisable to have sight-glasses A, one opposite to the other on the lid, so as to be able to watch the progress of the operation. It is also necessary to make provision against boiling over, by means of a dome or otherwise, in the case of liquids which produce a great amount of froth. There are many minor details of construction which distinguish different makes of vacuum apparatus made by reputed firms. Some vacuum pans are supplied with pipes through which the liquid can circulate, and therefore offer a greater surface to the heating steam; some have means of discharging salts which separate out, without breaking the vacuum. All these improvements add to the efficiency of the apparatus, but they also add to its cost, and sometimes by their complication cause frequent breakdowns. Where the condensing water is sprayed into the condensing tower, it will be advisable to ensure that the water enters the tower under as little pressure as possible, as otherwise a back pressure will be produced, which will reduce the vacuum, or at any rate, will render it more expensive to keep up a good vacuum. As the temperature at which a liquid will boil varies with the pressure, or to put it more clearly but less scientifically, as it is to some extent inversely

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proportionate to the vacuum, it follows that the better the vacuum which is kept up in the apparatus, the lower will be the temperature at which the evaporation will take place, and the higher the efficiency of the whole apparatus. With a moderate vacuum, water will boil at 50°C.; thus it follows that the steam which is used for heating the vacuum apparatus will do its work as long as it is above this temperature; so that, whilst in an open apparatus it would be necessary to work with steam of over 100°C., with vacuum apparatus, steam even at 50° C. will produce a sensible

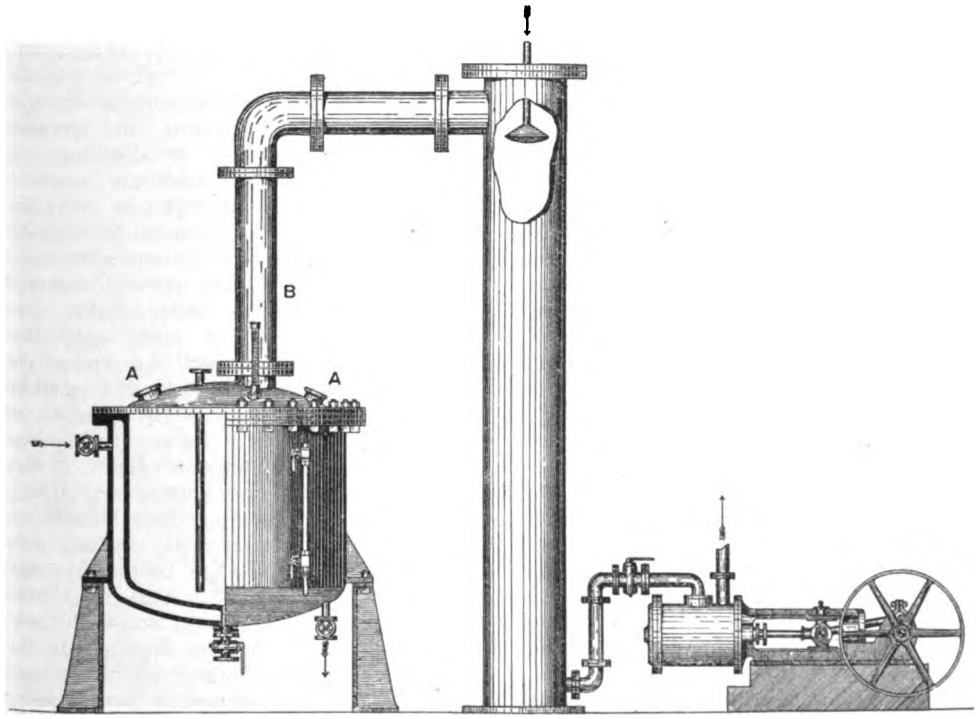

FIG. 13.—VACUUM DISTILLING PLANT.

evaporating effect. It is here, therefore, that the exhaust steam from engines, which in most cases has a temperature not much over 100°, will be found particularly effective and economical. As the boiling point of any liquid is lowered in a vacuum, it is possible to distill substances by means of steam, which otherwise would not be amenable to that agent; one could *e.g.* distill a substance boiling at 200° with steam of 150°C. On the other hand, one has to be careful in evaporating liquids containing substances which decompose at certain temperatures, not to use the steam at too high a temperature, otherwise these substances, notwithstanding that the operation is performed in a vacuum apparently kept below the decomposing temperature, may partially decompose. The reason for this is that the sides of the vessel become heated temporarily, to nearly the temperature of the heating steam; and though the liquor in the pan would be exposed to that temperature only for a very short time, a slight decomposition would take place at the contact points, and in the time required for an operation, might cause serious loss. In such cases, again, evaporation in a vacuum often enables us to utilise waste steam with great advantage. Where waste steam is not available, and where the steam which comes direct from the boiler has to be reduced in pressure, and consequently in temperature, this is done by an apparatus which is called a reducing valve—a simple contrivance which consists of a valve regulating the flow of the steam so that it expands in such a ratio as to reduce its temperature and pressure. If we heat a liquid by means of closed-in steam (that is, by means of a jacket, coil, or similar arrangement), steam is ultimately evolved from that liquid. There is no reason why this steam should not be conducted into the jacket of another pan or through a steam

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coil or similar arrangement, and made to heat up a further quantity of liquid and produce steam again, though of lower temperature and pressure. An arrangement of such a system is practically feasible, and is known as "multiple effect evaporation." Two apparatuses coupled together represent what is termed double effect: three, triple effect: four, quadruple effect, etc. It is possible thus to utilise heat for the purpose of evaporation more efficiently than by any other system, but it does not follow that an arrangement of this kind will always be the most economical to work. The cost of evaporation, in every case, is composed of a number of factors, including the cost of coal required to evaporate the liquid, the cost of labour in attending to the boiling down, the interest and depreciation on the outlay for plant, the repair for the same, and other general charges which we need not consider at present. If, for instance, we found that in order to boil down a certain quantity of water (say 1,000 gallons per day), we required one ton of coal at ten shillings: if the labour in attending to the pan came to four shillings: and if the total cost of the apparatus were £100, and the wear and tear of this, including interest on the money laid out, came to £15 per annum, which is one shilling per day; the total cost of evaporation would come to fifteen shillings per thousand gallons. If, on the other hand, we found that the original cost of the installation for multiple evaporation were £1,000, which, at 15 per cent. would represent £150 per annum, or ten shillings per day, we should find that even if the labour and other expenses were the same as with an ordinary boiling-down pan, the cost of evaporation would be still higher by that system, although the amount of coal (or rather its equivalent in steam) used for evaporation might only come to three or four shillings per day, against the ten shillings which we had to spend on fuel in evaporation in open pans by direct fire. These calculations do not represent actual facts, but are intentionally exaggerated, so as to show the student the necessity of not being misled by taking only one factor into consideration when the cost of an operation has to be considered. There is little doubt that the principle of multiple evaporation will, in the future, play an important part in the construction of evaporating apparatus. At present, the apparatus in many cases is still too complicated and too costly, and is therefore not used to the extent which it deserves. We have not gone into the theory of this most interesting part of chemical engineering, as it would require the use of mathematics, and the application of thermodynamics. Without these it would be impossible to give a satisfactorily scientific explanation of the principle of multiple evaporation. The fact cannot be too strongly emphasised that a knowledge of physics is quite as necessary to the technical chemist and the chemical engineer, as a knowledge of chemistry. It will well repay the student if he will try and work out for himself the theory of multiple evaporation; or, if his knowledge of physics and mathematics should not enable him to do so, to recognise the importance of acquiring that knowledge, and not to rest satisfied until he has done so.

We may now proceed to consider the construction of an apparatus used for what is generally understood as distilling. A convenient example of such an apparatus is presented in the manufacture of nitric acid. In the laboratory, nitric acid is generally prepared by mixing sodium nitrate and sulphuric acid in a glass retort, connected with a receiver which, being cooled, condenses the vapours of nitric acid that are given off. It is well known to the student of chemistry that this method of preparing nitric acid is capable of various modifications. To start with, one may aim from the outset at obtaining a very strong nitric acid, one approaching HNO_3 as near as possible; or one may be satisfied with obtaining a weaker acid, say one only containing 66% of HNO_3. In the one case it would be necessary to use pure dried sodium nitrate, and strong sulphuric acid containing at least 98% of H_2SO_4. In the other case, ordinary commercial nitrate, and sulphuric acid of commercial quality (of a specific gravity of 1·75, and equal to about 80% of H_2SO_4 in strength) may be employed. Moreover, the quantity of acid may be chosen so as to yield a product in the retort which may be either Na_2SO_4 or $NaHSO_4$, or a mixture of the two. If the proportions between sulphuric acid and nitrate of soda are chosen in such a way that they may be represented by the equation

$$2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3,$$

then the remaining mass in the retort will be sodium sulphate in such a form that it will be impossible to remove it from the retort without breaking the latter. If the operation is carried on in such a manner that it may be represented by the equation

$$2NaNO_3 + 2H_2SO_4 = 2NaHSO_4 + 2HNO_3,$$

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then the mass which will be formed in the retort will melt at the comparatively low temperature which is necessary to produce the liberation of nitric acid, and it will be possible to pour out the molten sodium-hydrogen sulphate at the end of the operation without breaking the retort. One difficulty will have presented itself in putting together the distilling apparatus; that is, how to make the connection with the retort and the receiver tight, as hot nitric acid will attack cork, rubber, or any other of the materials which are generally used for the purpose of making joints in ordinary laboratory work. With the facilities which one now has in getting glass apparatus of this kind, this difficulty is often overcome by having the retort neck ground into the neck of the receiver.

If we now consider how we may construct an apparatus suitable for manufacturing large quantities of nitric acid, we must bear in mind all the points which we have explained in connection with the laboratory work. We shall first have to decide whether we shall work in accordance with the first or the second equation which we have given above. In practice, it is not usual to go as far as $2H_2SO_4$ in the second equation; generally one and a quarter or a little more is taken, *i.e.*, just sufficient to form a compound which will melt at the temperature at which the retort is kept, and therefore will enable us to run off the charge in the retort when the operation is finished. If the proportions chosen are two $NaNO_3$ to one H_2SO_4, so that Na_2SO_4 results as the end product in the retort, it will be necessary to use as a still such an apparatus as will enable us to chip out the contents of the retort after each operation. For this purpose, a cylindrical vessel, about five feet long and about two feet in diameter, is generally used; this is provided with a cover in front which is taken off after each operation, and thus enables the workman to chip the sodium sulphate (or salt-cake, as it is generally termed) out of the retort. Apart from the extra labour which this involves, it is also necessary to cool the apparatus for about twenty-four hours before it can be opened and emptied, and got ready again for another charge. In this mode of working, there is a saving in sulphuric acid, and the product obtained is commercially more valuable; but the relative charges for labour and interest on installation, and the loss in fuel caused by the heating up and cooling down of the apparatus between the charges, are considerable. For this reason it is often preferable to use such an excess of sulphuric acid as to produce a mixture of sodium sulphate and hydrogen sodium sulphate in the retort; this, being melted at the end of the operation, can be let off through a convenient tap hole, leaving the still ready for another charge without loss of time and with little expense for labour. In an apparatus which is designed for this purpose, the still will have the shape of an ordinary pot with a round cover on it, similar to the one shown in Fig. 13; the dimensions of these pots vary considerably, to hold charges from a hundredweight to one ton and more of nitrate of soda. They are provided with a pipe going through the lid, through which the sulphuric acid is passed into the still; there is also a charging hole sufficiently large to enable the workman to throw in the nitrate of soda with a shovel; there is further a connecting piece on the top, to which the earthenware pipe conveying the nitric acid vapours to the condensing plant is secured. We have already mentioned that there is a convenient tap-hole at the bottom of the still, for letting off the molten residue. The still and all these parts are made of cast iron, as this resists the action of sulphuric acid down to acid of 80 per cent. fairly well. But there is some action, and it is necessary to allow for the gradual eating away of the iron, and to make the bottom part of the still, as far as it is touched by the sulphuric acid and the acid sulphate, of sufficient thickness—two inches or more in thickness. It is further necessary to brick in a still of this description in such a manner that the nitric acid vapours cannot condense in the upper part of the still and on the lid, as the fumes of nitric acid do not act nearly so strongly on the iron as the condensed acid does. The fire gases are, therefore, conducted round the pot, as we have shown in previous examples; in many cases they are taken over the lid of the still, though this complicates the matter considerably, and the same effect can be obtained by other means.

Having settled the form which our laboratory retort would have to take to enable us to prepare nitric acid on a large scale, and the material from which it would have to be constructed, we may now consider how to deal with nitric acid vapours so as to get them condensed. First of all, we must ascertain the material of which the condensing part will have to be constructed. Iron is naturally out of the question, as it would be destroyed, and at the same time would reduce the nitric acid to its lower oxides; no

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other metal could be used except platinum, which would be too expensive. We are therefore compelled to use earthenware. Fig. 14 shows different kinds of apparatus used for the purpose; a number of receivers A,A, may be combined with a plate tower B, and an earthenware worm C; or receivers only may be used, and the last traces of nitric acid may be washed out in a tower filled with earthenware solid or hollow balls, over which water or sulphuric acid is passing. Here we meet with the difficulty which we have mentioned in discussing the process as carried on in the laboratory, *viz.*, the joining up of the different parts. This, in practical work, is effected by means of lutes or cements, which are filled into the interstices at the junctions; thus the socket D would be filled in with cement as far as it would hold the latter after the pipe E had been placed in position. Naturally it will be necessary to choose such a lute as will resist the action of nitric acid vapour, and a number of these lutes or cements are recommended for the purpose. It will be sufficient to mention only a few. Thus, where it is desirable to allow a certain amount of play on account of expansion by heat, or for other reasons, a plastic lute which does not set hard is advisable: for instance, one made by heating up linseed oil with sulphur and old india-rubber cuttings, and incorporating barium sulphate and asbestos fibre in the resulting mass. Where a hard setting cement is required, a mixture of sodium silicate and ground glass may be used.

The principle of condensation is analogous to that of evaporation. One may cool by air, or by water, or by freezing mixtures; but in every instance the apparatus, to be efficient, must be constructed in such a manner that the largest surface is presented to the cooling medium.

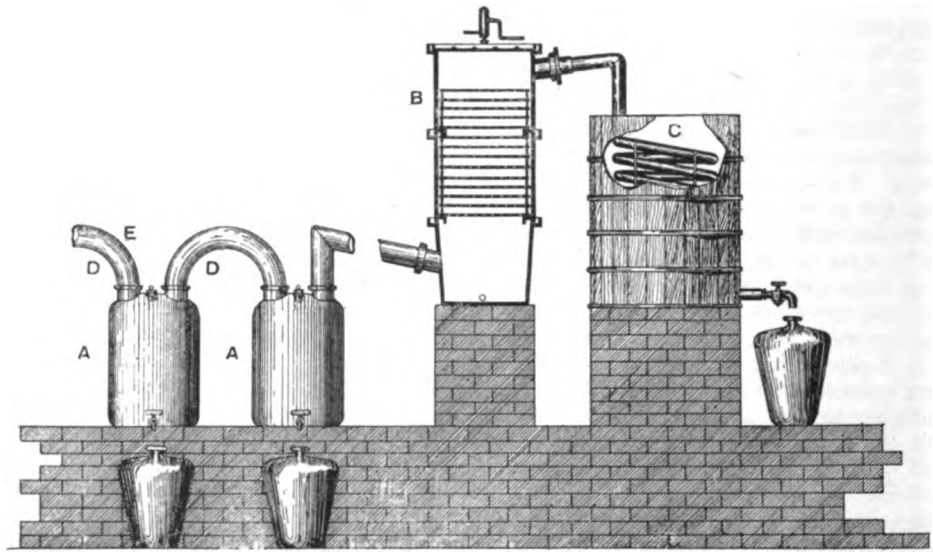

FIG. 14.—RECEIVING APPARATUS USED IN PRODUCING NITRIC ACID.

The example on which we have demonstrated distillation shows how important it is to carefully study the chemical reactions which take place, so as to design the apparatus accordingly; how necessary it is to consider the action of the chemicals used and produced, on the material of which the separate parts of the plant are composed; and how even the smallest details (as in this instance suitable jointings) must be attended to. Many modifications of distilling and condensing plant will be found in technical work, but they should present no difficulties to the student who has carefully read and understood the foregoing remarks.

(*To be continued.*)

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FRICTION CLUTCHES.

By GEO. A. F. POVER.

EVERY engineer is familiar with friction clutches in one form or another: in fact, the ordinary cone clutch is a very old invention; it is only, however, during the last few years that engineers and others have seriously attacked the problem of designing an efficient clutch. A search through the Patent Office records would show that there are numerous clutches patented, each of which (according to the patentee) is perfect and meets every requirement; but is this so? Let us look into the question as to what constitutes a perfect clutch. Mr. Walter Bagshaw, before the Institution of Civil Engineers (session 1886–7), stated the following to be the essential requirements of a clutch:—

1. Positive reliance at all speeds and under severe and sudden strains.
2. Ease in throwing in and out of gear whilst in motion.
3. Freedom from shocks.
4. Non-liability to wear or derangement.
5. No tendency to work out of gear.
6. Last, but not least, moderate price.

Professor Hele-Shaw, in a paper read before the Institute of Mechanical Engineers in 1903, gives the following four conditions as being involved in the problem:—

1. The clutch must have sufficient gripping power.
2. Undue wearing of the surfaces must be avoided.
3. Provision must be made for conveying away the heat, when there is much slipping of the clutch.
4. Motion should be imparted to the driven shaft without shock.

Thus we see that, at the outset, we have to meet conditions which, according to mechanical science, we are unable to reconcile.

Speaking for myself, having had considerable experience in this matter, I do not believe there is a single clutch at present made which would meet all the above requirements under every condition it is possible to name. At the same time, I believe it would be possible to pick out a clutch from the number subsequently described, suitable to meet as nearly as possible the above requirements, providing that we know exactly under what conditions the clutch has to work. Let me give an example or two to show what I mean. Suppose we have a high-speed motor always running in one direction, developing a large H.P., and we wish to fit a clutch so that the work may be stopped, enabling us to keep the motor always running: is it reasonable to expect the type of clutch suitable in this case to work equally well when used to drive (say) a heavy rolling mill which is doing very excessive work, but at a low speed? Or should we fit an elaborate and expensive clutch to a pulley on the line shaft in an amateur's workshop, to do possibly less than 1 H.P.?

I shall now describe a number of characteristic clutches and give their advantages and disadvantages, and state under what conditions one type is preferable to another.

Take first the ordinary cone-clutch (Fig. 1). We here have the simplest form of clutch it is possible to make; one portion is keyed to the driving shaft, and the male portion slides on feathers on the driven shaft, the end of the driven shaft being carried in bush, which is secured to the driving portion of clutch. The advantages to be derived from its adoption are:—Low price, simplicity of construction, and small movement required to put in gear.

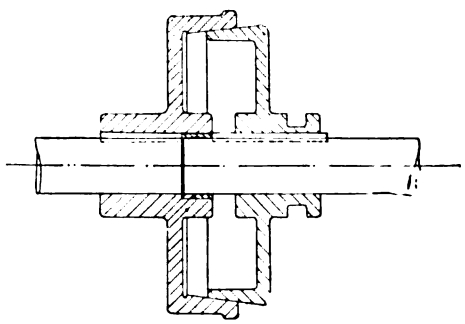

FIG. 1.—ORDINARY CONE CLUTCH.

The disadvantages are:—Destruction of surface if allowed to slip much, constant end-thrust on shaft, and liability to work out of gear.

In Fig. 2, we have one of the many modifications of the cone clutch. This is a clutch much used in one form or another on modern motor cars. It will be noticed that a band of leather is secured to the outside of the male portion of the clutch, whilst on the inside

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will be seen a guard fitted to prevent oil from the engine or gear-box reaching the leather. With proper attention and careful usage, this clutch is fairly satisfactory, but is liable to be

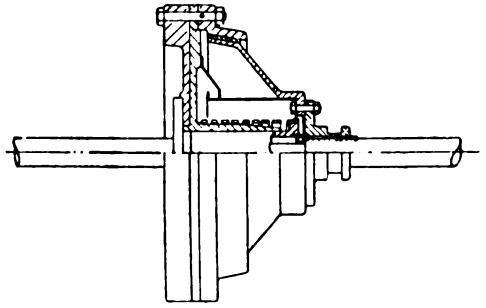

FIG. 2.—LEATHER-COVERED CONE CLUTCH, FOR MOTOR CARS.

put out of use by oil getting on the leather, and by burning out—by no means a rare occurrence. Fig. 3 shows a type of clutch very suitable for light work. As shown, a disc of metal is cambered and attached to the sliding portion of the clutch which, on being

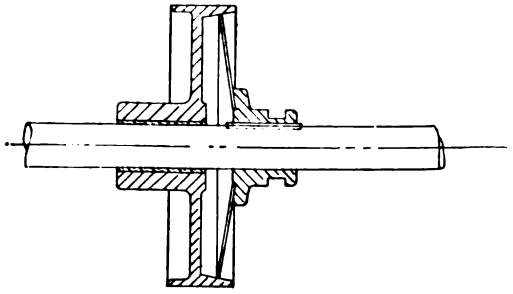

FIG. 3.—DISC CLUTCH, FOR LIGHT POWERS.

pressed into the pulley, engages with this. It is only suitable for the very lightest of work, as the friction surface is so small.

In Fig. 4 we have one of the many forms of drum expanding clutch, in which a ring or segments are forced into contact by wedges, right- and left-handed screws, toggle joints, etc. These clutches work well when doing light work if they are not required to slip much. If much slipping occurs, undue wear and much heating take place, which make frequent adjustment necessary, and in time destroy the surface. In Fig. 5 is shown the Weston clutch, in which the friction effect is produced by a number of circular discs, connected alternately with the driving and driven ends of shaft. With this clutch we might include the brush clutch, in which brushes of wire are thrust into a grooved plate.

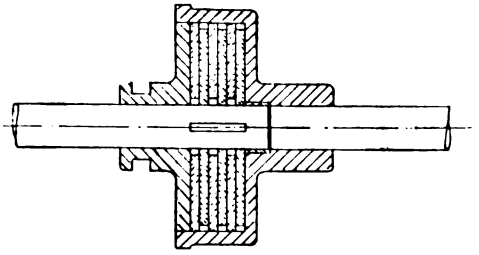

FIG. 5.—THE WESTON CLUTCH.

In my opinion, Fig. 6 shows a vastly improved form of this clutch, due to Professor Hele-Shaw. It will be seen that the plates and brushes of the preceding clutches have been replaced by corrugated discs of thin sheet metal alternately serrated on the outside and inside, to fit into grooves cast in the driving and driven portion of clutch. These clutches are made in various forms: some are air-cooled and others are enclosed, and run in oil. From experiments made, it would appear that where there is much slipping, and for high speeds, we have in this an ideal clutch. Whether the plates are liable to rapid wear is a point we cannot now decide, as the clutches

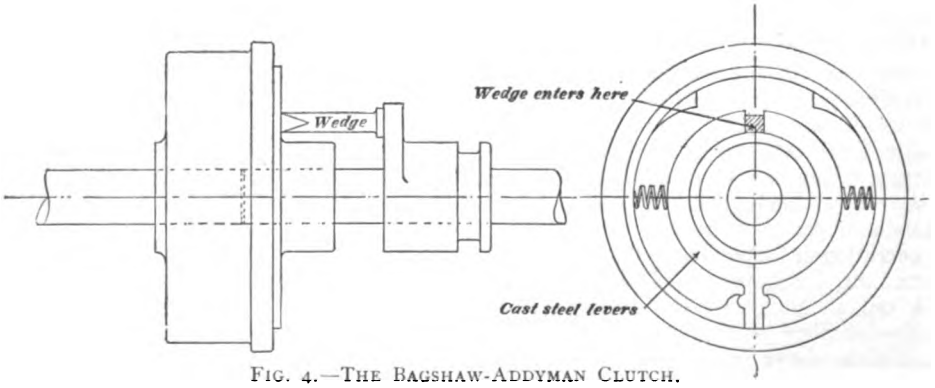

FIG. 4.—THE BAGSHAW-ADDYMAN CLUTCH.

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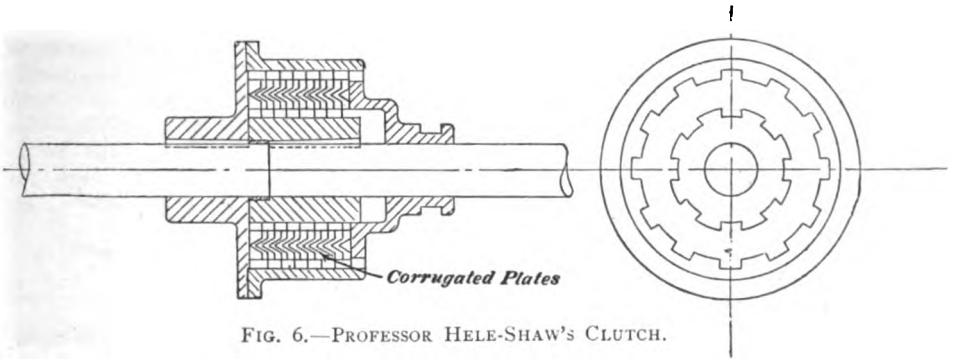

FIG. 6.—PROFESSOR HELE-SHAW'S CLUTCH.

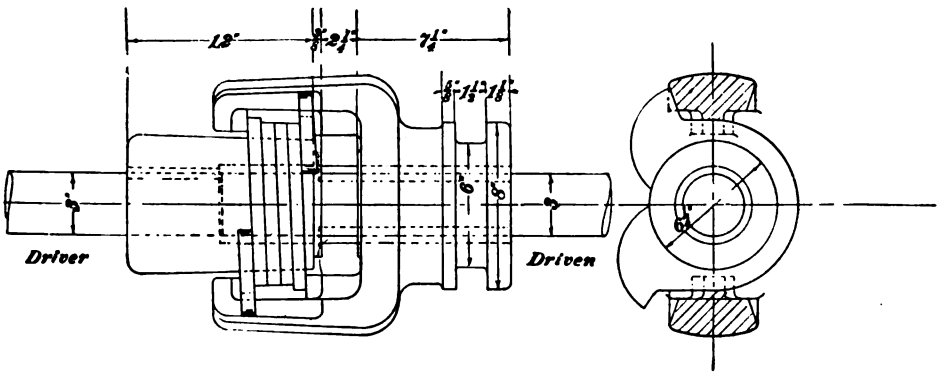

FIG. 7.—COIL CLUTCH (CLASS F).

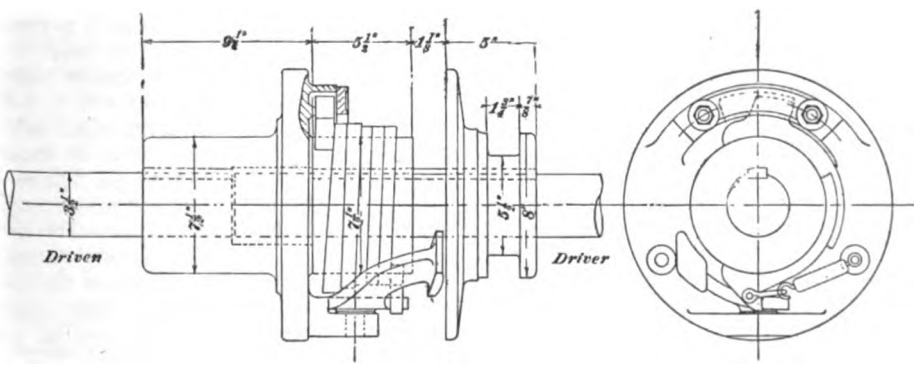

FIG. 8.—COIL CLUTCH (CLASS B).

are so little known and have not had the test of time.

We now come to an altogether different type of clutch, in which the well-known gripping power of a coil of steel or rope is made use of.

In Fig. 7 we have the simplest form of this clutch, in which a coil of steel with lugs at each end engages with a casting which slides on feathers and forces the coil on the cone, and thus causes it to wind up and grip. This clutch can be used to drive very heavy machinery; it has now been in use for a number of years, and for its particular duty is found to be entirely satisfactory. This clutch drives in both directions, a point in which it differs from other clutches of the same principle, which I have to describe. The only apparent objections are: space occupied; weight, and the amount of pressure required to put into gear. On this last point it must be remembered, that once the clutch is in gear, there is no end thrust whatever on the shaft.

In Fig. 8 is shown a type of clutch much in vogue for heavy work at speeds up to

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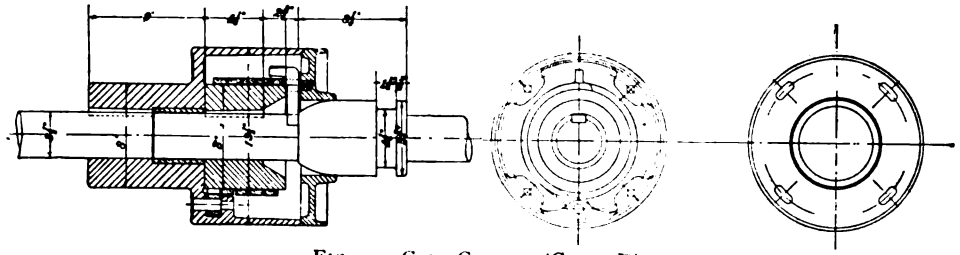

FIG. 9.—COIL CLUTCH (CLASS D).

150 revolutions per minute. The coil is still used, but it is fitted on a parallel drum, and is wrapped up by means of the bell-crank lever, this lever being pressed into position by means of the sliding disc shown. With this clutch there is always a certain amount of end pressure on the shaft, but at the speeds given this has not been found detrimental. When I mention that this type of clutch is used for reversing rolling mills (which are reversed, say, every thirty seconds), with drums 36 inches diameter, and 19-inch shaft, with an area at coil head of 36 square inches, it will be seen that these clutches are capable of work which seems incredible to people unacquainted with their capabilities.

The clutch shown in Fig. 9 has been designed to overcome the objections sometimes raised, of end pressure and unprotectedness of clutch. It will be seen that the principle is exactly the same, but the method employed for wrapping up the coil is different. In this case a vertical lever is attached to the cover plate of the clutch. This cover plate is slotted, as shown, so that any necessary adjustment may be easily made. The sliding portion engaging the lever is made spherical, so that when the clutch is in gear there is absolutely no end pressure on the shaft. As the clutch is entirely cased in and filled with oil, it is possible to work it with very little attention when once adjusted. This clutch picks up its load very smoothly, and is largely used for fitting to the pulleys of electric motors, when the work has to be stopped without stopping the motor.

We now come to the last clutch shown (Fig. 10), which I think is a radical departure from anything that has yet been made in the way of clutches. It is specially designed for motor car work, and in practice works to the entire satisfaction of everyone. It will be seen, although the coil is still in use, that there are many features which are new. The chilled drum is made hollow, and in this drum are holes through which oil is drawn by centrifugal action right to the part where it is required. This is a point which, I think, will overcome much of the trouble caused by heating. A lubricator is fitted to the cover, so that it is possible to feed the hollow drum with oil, although the motor may be running at 1,000 revolutions per minute. The method of wrapping up the coil is clearly shown, and is entirely under the control of the driver.

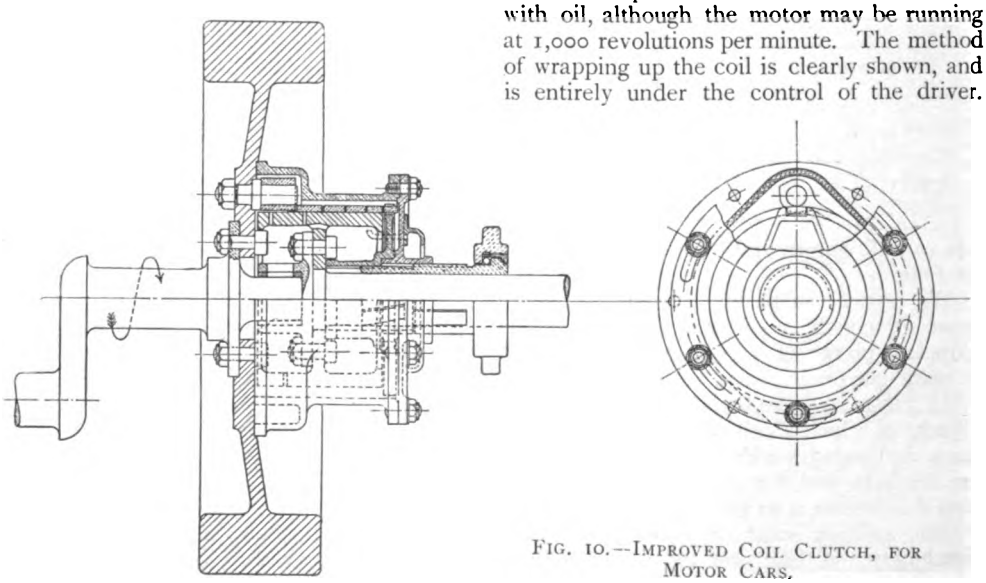

FIG. 10.—IMPROVED COIL CLUTCH, FOR MOTOR CARS.

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The weight has been cut down to a minimum, and when I say that the clutch shown only weighs one pound for every horse-power transmitted, it will be admitted that we have a clutch which should be in great demand by makers of all types of cars.

In conclusion I must acknowledge my indebtedness to Professor Hele-Shaw for much information, taken from his paper, concerning his type of clutch, and also to "The Consolidated Engineering Company" for the information that has been given me concerning coil-clutches.

SPECIAL DEVICES USED IN WEAVING.

Part IV.—Anti-Friction Devices for Pirn Winding Machines.

[*All Rights Reserved.*]

By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

ANOTHER type of anti-friction devices for pirn winding, patented by D. Sykes and W. Mitchell, is illustrated by an end and front elevation, in Figs. 17 and 18 respectively. This device consists of a pair of bevelled discs or cones H, H′ (in place of a stationary pirn cup), between which bobbins are built up with yarn. The discs are supported by, and revolve freely upon, studs X, X′, secured to brackets V, V′, fixed to a cross-rail. They are rotated negatively by their surface contact with bobbins G. These are supported vertically between their respective discs by means of spindles E and bolsters W; and are turned by the spindles, which pass centrally through them, and then enter rectangular holes in wharves D, which are driven in the usual manner by means of cotton bands C from a tin drum. As bobbins revolve, yarn is guided up and down along their respective cones by means of guides U, fast upon a guide rod T, which is carried by a number of arms S, fixed at intervals upon a rod R, extending one on each side from end to end of the machine. The resistance offered by the discs forces a bobbin and its spindle upward as additional layers of yarn are added to it, until it is filled, when its spindle withdraws from the hole in the wharve, and thereby automatically stops.

In the previous article under this head, it was stated that whatever form these anti-friction devices may take, and however they may be applied, *their success largely depends upon the surface velocity of a disc or bowl, and a bobbin cone, exactly coinciding at all their points of contact with each other, which condition may only be secured by shaping the discs or bowls so that their circumferences vary in exactly the same ratio as that of a bobbin cone.*

Judged according to that dictum, it is manifest that the device under present notice only partially meets the conditions stipulated, and does not, therefore, entirely eliminate friction between yarn and the discs, notwithstanding the patentees' assertion that the surface velocity of a bobbin cone, and of the discs, exactly coincide; and that there is, therefore, no friction upon yarn. Now, had the inventors of that device devoted a little more thought and care to its construction, they might have successfully achieved their object by a very slight modification in the shape of the discs, and also by placing their axes in a little lower plane in relation to the bobbin cone. As represented in Fig. 18, the major and minor diameters of the bobbin cone are in the ratio of twelve to five, and the respective surface velocities will be in the same ratio; whereas the ratio of the diameters and velocities of corresponding points on the discs are incomputable, by reason of the points of a cone being in the same plane as its absolute axis, and of infinite dimensions. It follows, therefore, that there will be a certain amount of slippage, and consequent friction, between

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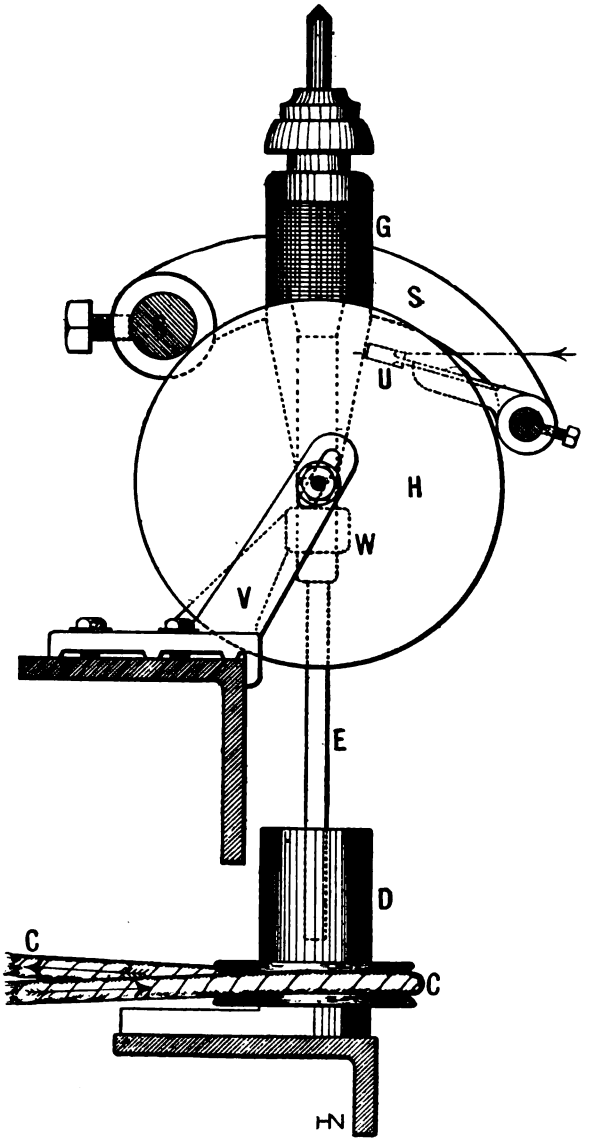

FIG. 17.—*End Elevation.*

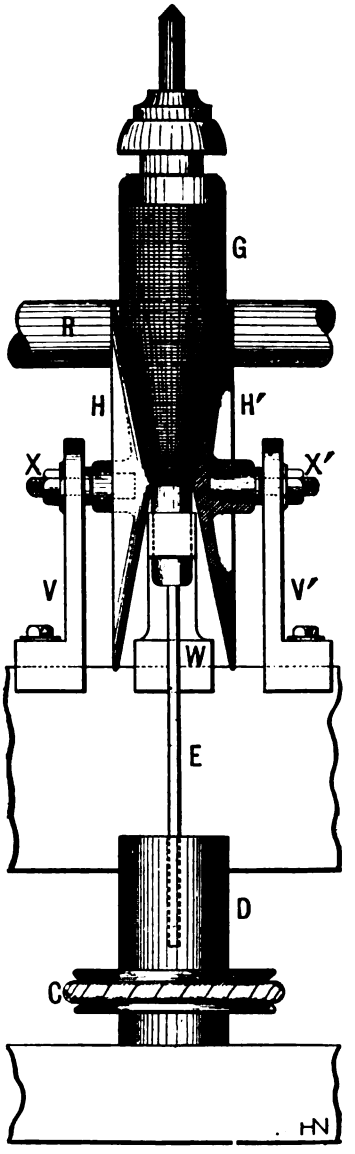

FIG. 18.—*Front Elevation.*

SYKES'S AND MITCHELL'S DEVICE.

the discs and a bobbin cone, which slippage gradually increases from the larger diameter towards the smaller diameter of the cone, at which point it will be at its maximum.

The method of obtaining the correct form of discs, and the correct position of their axes, is clearly demonstrated by a graphic diagram, Fig. 19. It is only necessary to produce one side of the bobbin cone AB, until it cuts the axis of the bobbin at C, which marks the exact position of the axis C D, of the discs. This will ensure the circumference of both discs and bobbin cones varying in exactly the same ratio; thereby ensuring the same surface velocity at all points of their contact with each other. This, of course, presumes the friction of discs upon their bearings to be *nil*—a condition which may be approached by means of ball bearings.

There are other equally glaring examples of the departure from the conditions necessary to ensure a perfect rolling contact of bobbins with another surface against which they are

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built up. Such departure is exemplified in all instances in which conical bowls or rollers are so placed that the larger diameter of a bowl is contiguous with the smaller diameter of a bobbin cone (and per contra) as seen in Fig. 20. This diagram illustrates the wrong application of conical bowls in a pirn winding machine, and is one of numerous examples of a similar kind that will serve to demonstrate the misconception under which their inventors appear to have worked.

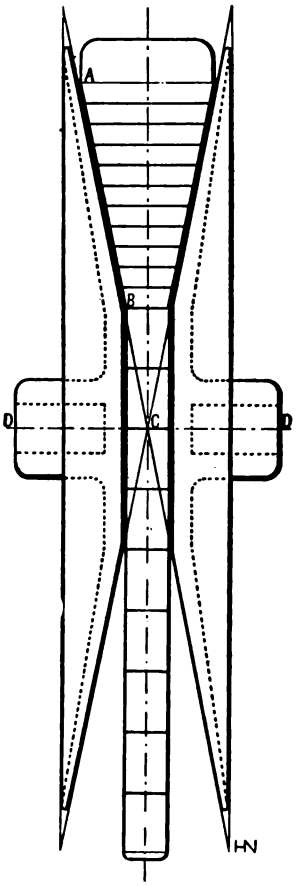

FIG. 19.—SHOWING THE CORRECT METHOD OF DESIGNING BEVELLED DISCS.

The machine under present notice contains a series of metal conical bowls E, fixed at the top of vertical spindles or shanks D, supported at regular intervals by a rail H, with such distance between their surfaces as will permit of a pirn bobbin F resting vertically between them, with its head uppermost. The cones are placed with their larger diameter downward, and their smaller diameter upward. The shanks or spindles of cones are furnished with flat discs C, which bear against the peripheries of revolving discs B, fixed upon a driving shaft A, placed one on each side of the machine. Hence the cones are frictionally driven, and they in turn drive bobbins also by frictional or surface contact. Bobbins are supported in position by means of long spindles G, which pass freely through them, and enter bolsters (not shown) fixed upon a cross-rail. Thus, as a bobbin fills with yarn, the resistance of the cones forces it, with its spindle, upward, until the spindle withdraws from its bolster, when it automatically stops. With such an application of conical bowls, it will be readily manifest, even to a casual observer, that there can only possibly be one point of their contact at which the surface velocity of a bowl and a bobbin cone can coincide. It will, therefore, slip at all other points of contact. The point of coincidence probably occupies a mean position between the extreme diameters of the cones, or else a point nearer the smaller diameter of a bobbin cone. That this and similar imperfect devices have found any measure of appreciation from manufacturers is evidence of the serious character of the defects which they are designed to overcome, and of their readiness to adopt means that will even partially fulfil their object.

It is satisfactory to note, however, that more recent inventors have learnt the correct application of the principle of a rolling surface contact for pirn winding. One of the earliest devices constructed on right principles is that in which three wooden or metal conical bowls are employed in lieu of a pirn cup. One of numerous modifications of that arrangement is shown in elevation and plan in Figs. 21 and 22 respectively. Three exactly similar metal cones are placed triangularly in an inverted position, so that their larger diameters are upward, and their smaller diameters downward. The cones are each furnished with a tightly-fitting pin passing centrally through them, and pointed at each end; and are contained in a bracket consisting of a base, cast with two pillars to support a crown (not shown in plan). The lower extremities of cone pins enter fixed sockets in the base; whilst the upper extremities enter sockets in adjustable caps set-screwed to the crown. Thus, the angle of the cones may be adjusted to suit different sizes and shapes of pirn bobbin heads, which, during winding, rest between and against the cones, and are turned in the usual manner by means of spindles and wharves driven by cotton bands from a tin drum. The bearings of cone pins require to

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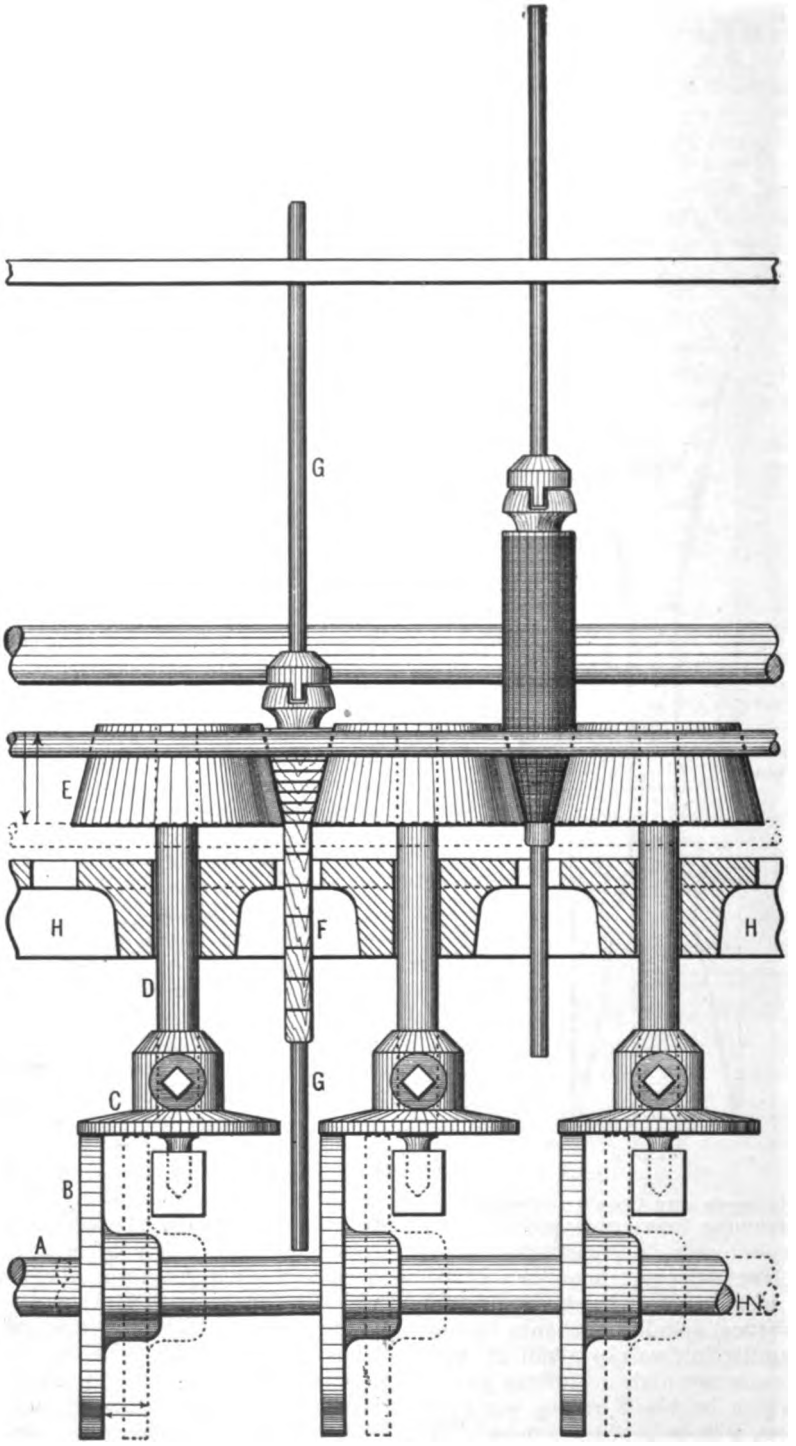

FIG. 20.--PART FRONT ELEVATION OF CONE PIRN WINDING MACHINE.

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be kept well lubricated, and free from yarn and lint, to ensure the free rotation of cones by their surface contact with a bobbin. Another modification of the three-cone system is shown in perspective in Fig. 23. In this device the cones are supported by, and revolve upon, spindles that are secured to adjustable pieces set-screwed to the base, thereby permitting of their adjustment.

A more recent application of cone winding, and one that appears to have met with considerable success, is exemplified by those machines in which a single inverted metal cone is employed, against which a bobbin is firmly held as it is built up with yarn. Fig. 24 is a part elevation of a single-cone pirn winding machine, on each side of which are fixed a number of brackets O, each containing a conical bowl P Bobbins F are held in close contact with their respective cones by means of spindles E suspended from holders G which slide in brackets H. The lower ends of spindle shanks enter rectangular holes in wharves D, by which they are driven; the wharves being driven by means of cotton bands C, from a tin drum B. Spindle holders G are suspended by means of wire links from weight levers I, fulcrumed on pins J, contained in vertical arms K, of brackets H. Weight levers each contain two weights. One of these, L, may be adjusted so as to impart a greater or lesser degree of pressure of a bobbin against its cone during winding; whilst the other, M, is a balance or compensating weight that slides freely upon the lever as the latter changes its position, to compensate for the increasing weight of a bobbin as it fills with yarn. This is accomplished by means of a wire link N, fulcrumed at one end, to arm K, with the other end attached to a hook on weight M. Thus, as a bobbin rises, and the rear end of lever I falls, weight M gradually recedes from the fulcrum, thereby increasing its force upon the lever, and counter-balancing the increasing weight of a bobbin.

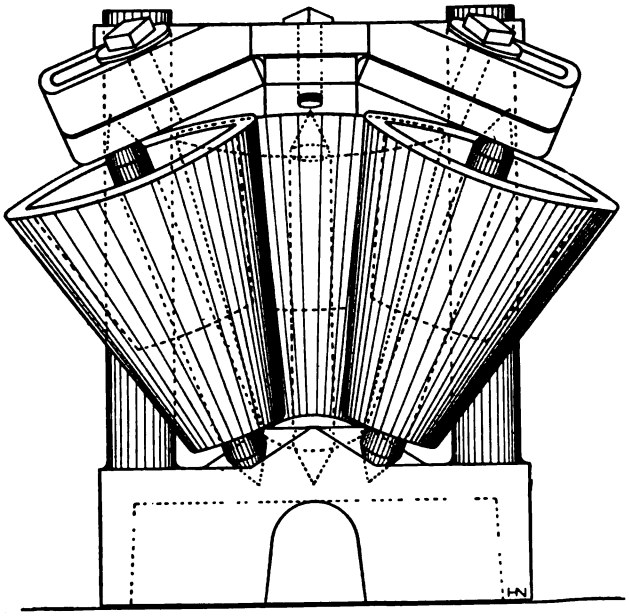

FIG. 21.—ELEVATION OF A THREE-CONE DEVICE FOR PIRN WINDING.

Yarn is guided up and down along the bobbin cones by means of guides actuated from cams T, shaped so as to give a slow upward and a quick downward traverse (the velocity being in the ratio of one to two respectively), whereby threads are placed upon their respective bobbins in alternate

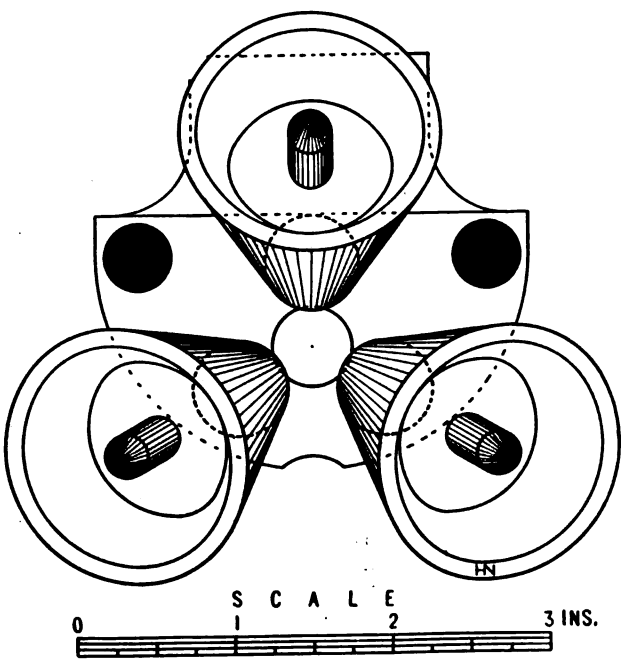

FIG. 22.—PLAN OF A THREE-CONE DEVICE FOR PIRN WINDING.

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layers of a close and open spirality (as in mule cops), thereby causing them to cross and re-cross, and bind themselves more compactly than is possible with a uniform traverse in both directions. An alternative method of actuating yarn guides is by means of an eccentric U, fixed on one end of the tin drum shaft A.

Before bringing to a conclusion these observations on anti-friction devices for pirn winding, it is desirable to again emphasise the italicised statement contained in the second paragraph of the present article, having reference to the shaping of discs or bowls, so that their circumference varies in exactly the same ratio as that of a bobbin cone. That statement is true under any conditions, and quite irrespective of the number of cones to each bobbin, as one, two, or three. The condition therein set forth may only be observed in the following circumstance, namely: *where the sides of the conical bowl or bowls, and also of the bobbin cone, all converge to a common point*, which point must, of course, necessarily be somewhere on the axis of a bobbin. This

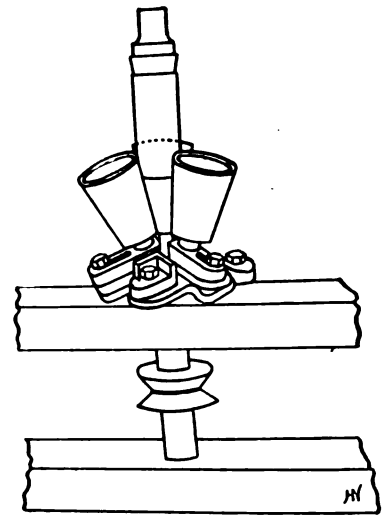

FIG. 23.—A THREE-CONE DEVICE FOR PIRN WINDING.

is graphically demonstrated in Fig. 25, where a pirn bobbin A is represented between two cones (B and C) of different angles, namely,

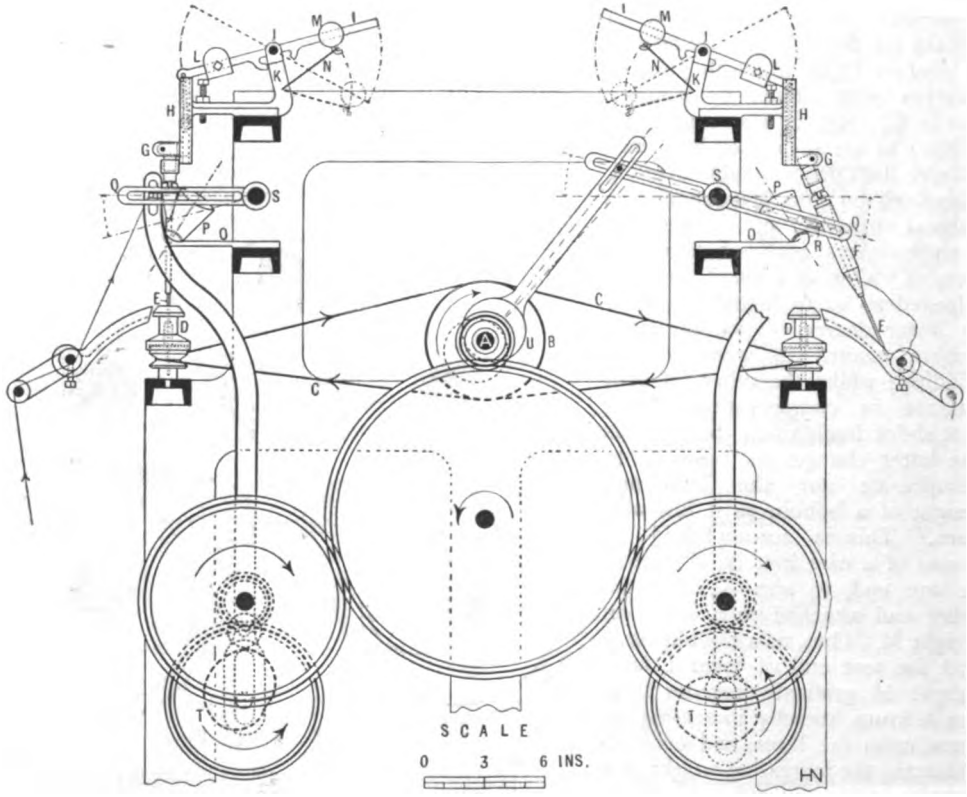

FIG. 24.—PART ELEVATION OF A SINGLE-CONE PIRN WINDING MACHINE.

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30 degrees and 45 degrees respectively. The sides of the bobbin cone are produced until they meet on the axis of the bobbin at point D, which marks a common point from which the sides of a cone or cones should diverge, as shown. Thus, notwithstanding the difference in the angles of the two bowls, and the different positions of their axes, in relation to the axis of the bobbin, their diameters, and also the diameter of the bobbin cone, *all vary in exactly the same ratio; therefore* (in the entire absence of frictional resistance) *their surface velocities would exactly coincide at all their points of contact with each other.* It is proved, therefore, that the angles of the cones may be of any practicable number of degrees, and that they may be placed in different relative positions to the axis of a bobbin, provided the condition just set forth is adhered to; but in proportion as that condition is departed from will the surface velocities of bowls and bobbin cones vary.

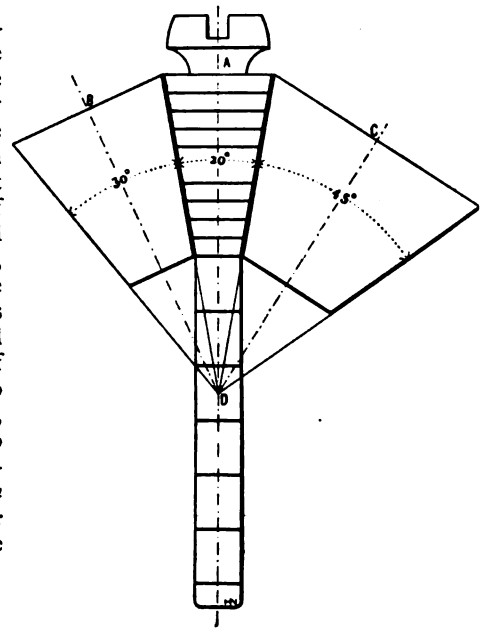

FIG. 25.—DIAGRAM SHOWING THE CORRECT FORMATION AND APPLICATION OF CONICAL BOWLS FOR PIRN WINDING.

(*To be continued.*)

INSULATION AND INSULATORS.

By HAROLD D. SYMONS.

Paper read before the Students' Section of the Institution of Electrical Engineers, April 27th, 1904.

PART I.—INSULATION—(*continued from page* 90).

THE next point which naturally arises is as to whether dielectrics waste power under high alternating potential stresses. Does dielectric hysteresis play an important part in the losses which go on in a cable?

In all tests which have been carried out to determine the loss in the dielectric, it is extremely difficult to say how much was due to dielectric hysteresis and how much was due to pure conduction, for insulators undoubtedly do conduct.

Although it is not impossible to conceive that a loss goes on in dielectrics, due to the rapid rate of change of E.M.F., analogous to the hysteresis loss of iron, yet the dielectric hysteresis loss must be extremely small. In view of the beautiful experiments carried out by Professor Threlfall and published in the *Physical Review* (see Vols. IV. and V.), a dielectric has a small hysteresis loss.

If we consider the case of a high voltage concentric cable at one instant, the rate of fall of potential will be greatest in that part of the dielectric which is nearest to the conductor at the maximum potential; but at another instant this conductor will be at zero potential, and the rate of fall of potential in this same portion of the dielectric will be at its lowest value at this instant. If dielectrics conduct in the same manner as conductors, a conductor wastes very little more power in conducting an alternating current than it does in carrying a continuous one, and therefore, owing to the high resistance of the dielectric, the loss by hysteresis could only be due to the magnetic effect of the alternating field upon it; but as its permeability is considerably less than unity, the loss due to magnetic hysteresis of the dielectric would be practically nothing. At any rate, it would be so small that, with our present methods of testing hysteresis loss, it

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could not be measured with any certainty. It may be, however, that the dielectric, as a bad conductor, has currents induced in it due to the rapidly alternating field, and that this is a source of loss.

It is more probable that insulators do not conduct in the same way as conductors, but it is difficult to conceive that this is so, if the dielectric is homogeneous.

Any dielectric which has absorption must waste power. This, however, is a property which conductors have not apparently got; but if a dielectric which showed absorption could be tested at such a frequency that it would have no time for absorption to take place, the author is of the opinion that it would be found that practically no power was lost due to dielectric hysteresis.

loss in a dielectric other than by conduction is absorption; but a dielectric showing considerable absorption, will have a comparatively low disruptive strength.

From what has been said, the next question is, if insulators conduct, how do they conduct, and do they obey Ohm's law?

There are some substances, such as graphite, of which it can be said that they are neither insulators nor conductors; but they have a sufficiently high resistance to be used for the insulation of armature core plates, and at the same time do not prevent continuity of iron. There are others, also, which under different conditions are either insulators or conductors.

Ice, and water (if purified in a vacuum and not allowed to come into contact with the

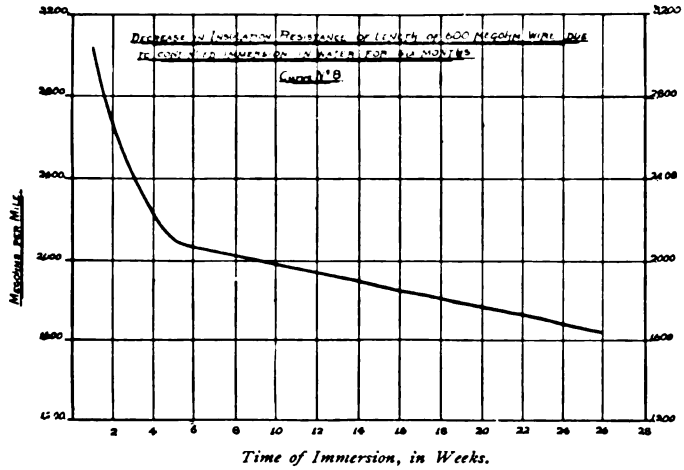

FIG. 8.—CURVE SHOWING DECREASE IN INSULATION RESISTANCE DUE TO IMMERSION OF INSULATED WIRE IN WATER.

If any dielectric does waste power in this or any other way, after the loss has been shown not to be either by conduction or absorption, it is probably due either to air holes or to the presence of some foreign matter in the dielectric, which produces either disturbance or irregularity in the rate of fall of potential through the dielectric; and the reason that the author is of this opinion is that dielectrics, such as oil, which are able to be manufactured or obtained very nearly homogeneous throughout, show very little loss of power under high alternating potentials, and what loss there is is probably due to conduction; whereas dielectrics which are by no means homogeneous, such as air, show apparently a comparatively high loss other than by conduction.

The most probable cause of appreciable

air) are good insulators, but ordinary water is a very good conductor; selenium under the influence of light conducts, but if placed in darkness its resistance rises so high that it may be said to be an insulator; they are, however, only insulators as regards their ohmic resistance, as, except ice, they have no great disruptive strength.

It is certain that neither gutta percha nor paraffin obeys Ohm's law, but undoubtedly some dielectric liquids do: if insulators obey Ohm's law, then their resistances should be the same with all E.M.Fs.; but tests tend to show that it has been almost impossible to obtain the same resistance (at any rate, with cables) with various E.M.Fs.

Mr. O'Gorman, in his paper on the Insulation of Cables, read before this institution in March, 1901, attributes the discrepancy in

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results to leakage loss at the ends: after some careful work in this direction, however, the author is of the opinion that the irregularity of results is due to the fact that at the high voltages the rate of electrification tends to be higher than it does with the lower voltages, as the insulation resistance of a dielectric will vary with the time the voltage is applied, although for the convenience of comparison of tests it is always taken at the end of one minute; the difficulty of ensuring that the temperature of the cable has been the same throughout the tests has also probably affected the results of the tests which have been made and published (see Mr. Siemens, in discussion on Mr. Preece's paper, Vol. 21, p. 216, Journal of Institute Electrical Engineers).

If Ohm's law holds good with dielectrics, increasing the thickness of dielectric should proportionately increase the insulation resistance: increasing the thickness does increase the insulation resistance, but whether in the same proportion seems doubtful.

The author has taken great pains in carrying out numerous tests to endeavour to prove this, but the tests of plates of various thicknesses of dielectrics are affected by atmospheric conditions to such an extent that it has been found impossible to obtain results which are of much value, or at all conclusive; from the results of the author's experience, however, if it were possible to obtain samples of uniform thicknesses of the same dielectric absolutely homogeneous throughout, and their molecular construction identically the same, he is of opinion that it would be found on testing these and eliminating all sources of error, that those insulators which were chemical compounds or natural elements would obey some such law as that of Ohm, but that mixtures would not; this will mean that nearly all the insulators at present on the market do not obey Ohm's law.

This has, of course, no reference to the insulation resistance of cables, for as we proceed further and further from the centre, the area of each layer increases, and therefore successive layers of dielectric do not add equally to the resistance.

The insulation resistances of cables with the same dielectric will be proportional to the logarithms of the ratios of their external and internal diameters of dielectric.

However, Ohm's law cannot hold with dielectrics:—

1. Where there is any decomposition of the dielectric due to electrolytic action, and energy is used in bringing about this decomposition.

2. Where the dielectric is not homogeneous with regard to its specific inductive capacity, as the particles of higher specific inductive capacity tend to set themselves in the plane of the highest potential slope.

3. Where convection occurs, which always tends to take place when the electrical stress is high.

No. 2 would seem to confirm the author's opinions as to dielectrics obeying Ohm's law.

Three theories have been put forward as to how insulators conduct:—

1. By convection.

2. Electrolytically.

3. By an actual movement of particles from place to place.

If insulators conduct by convection, then those fluid insulators that obey Ohm's law cannot conduct by convection, as it would not occur if the fluid were viscous, and it is probable that all insulators conduct in the same manner.

If they conduct electrolytically, then Ohm's law cannot hold, as before stated; energy being used to produce the electrolytic action. Although it has not yet been definitely proved that dielectrics do not conduct electrolytically, at all events, if they do, the electrolytic action is extremely small.

The last theory, that of an actual movement of the particles from place to place, really seems to be the most probable one, especially in view of the experiments carried out by George Reams.

Reams carefully stripped, layer by layer, the gutta percha of a cable that had been used for twenty years, and found that the copper had actually penetrated every layer; similar results were found with paper and oil insulators; but in order to have made these tests more conclusive, the percentage of copper in each layer should have been determined, and the paper and oil dielectrics should be quite free from acids that might attack the copper.

So far as the author is aware, there are no published results of similar tests having been carried out with rubber, but it is probable that if such a test were carried out, it would be found that the copper had penetrated the rubber, due in all probability to the sulphur in the rubber acting on the copper through bad tinning.

There is a large field for research in this direction, and it would be of very great interest if some of the insulating oils that have been in use in transformers and oil break

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switches and fuses were analysed, to see if similar results were obtained.

If this is so, it may be that dielectrics waste power under high alternating potentials due to an actual mechanical vibration: at any rate, this theory would seem to be substantiated from the fact that the presence of conducting particles in a dielectric increases the inductive capacity, and as cables get older the inductive capacity increases, especially with gutta percha cables; this, however, may be due to the ageing of the dielectric.

It has been suggested that perhaps the conductivity of a conductor is affected by the dielectric which surrounds it: Sandford has experimented a good deal in this direction, and from his results he was of the opinion that the conductivity of a conductor varied with the surrounding dielectric: he however only employed vapour dielectrics, as air, ether vapour, coal gas, petroleum, etc., and found that whereas copper showed a lower resistance in petroleum than in air, the reverse was the case with silver.

This touches the question which has been raised with reference to the action of acids in the dielectric on the conductor, but Sandford's results showed that the difference in the conductivity of the conductor was so extremely small as to be within the limits of experimental error.

It, however, emphasises one fact, which the author is of the opinion has been too much ignored, that a good dielectric must be chemically inert; it is possibly for this reason, and also from the fact of its being unaffected by long immersion in water, that gutta percha has proved itself such an excellent insulator. Bitumen is chemically inert, and may prove itself to be of considerable value in the manufacture of power cables.

If two similar condensers are electrified from the same source, they will attain the same potential; but the charges they receive will be proportional to their capacities. By determining the ratios of these charges, the ratios of their capacities is determined; if air be the dielectric used in one condenser, Faraday called this ratio "specific inductive capacity," and Maxwell, the "dielectric constant."

There have been many attempts made to obtain the specific inductive capacities of substances *; it would seem, however, that this is affected by temperature (especially at very low temperatures †), but not within such wide limits as the specific insulation resistance.

Attempts at determining the specific insulation resistance have been very discouraging, it being impossible to obtain anything like uniformity of results. The insulation varies enormously with the temperature.

Maxwell pointed out, in his electro-magnetic theory of light, that a certain definite relation must exist between the index of refraction and the dielectric constant of a medium transmitting light, and that the specific inductive capacity multiplied by the permeability is equal to the square of the index of refraction.

All transparent solids are insulators, but it is doubtful whether this law can be universally applied ‡ to all insulators.

The relationship between specific inductive capacity and specific insulation resistance is very difficult to determine.

As before stated, particles of higher specific inductive capacity in a matrix of lower specific inductive capacity tend to set themselves along the lines of highest potential slope, and this is doubtless the cause of breakdowns with dielectrics containing impurities.

If a dielectric has a high specific inductive capacity, it also has a low specific insulation resistance, and *vice versâ;* this, however, is not always so, as by a careful mixture of some dielectrics, an insulator may be produced that has a low inductive capacity and a low insulation resistance.

Such a dielectric, however, is apt to have electrical absorption, and is likely to absorb moisture; the presence of moisture in a dielectric is disastrous, as it will increase the inductive capacity, water having a very high specific inductive capacity.

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* See "Phil. Magazine," Vol. XLIV., p. 404, 1891; "Phys. Review," Vol. XII., pp. 50–52, January, 1901; "Phys. Review," Vol. IV., p. 479, and Vol. V., p. 46, 1897.

† See *Electrician*, Vol. XXXIX., p. 645, or "Proceedings of Royal Society."

‡ See Professor Threlfall's results in "Phys. Review," Vol. V., p. 65.

(To be continued.)

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ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES.

PART VI.—MISCELLANEOUS USES OF THE ELECTRIC CURRENT FOR CHEMICAL PURPOSES.

By JOHN B. C. KERSHAW, F.I.C.

Oxygen and Hydrogen.

THE electrolysis of an acidified solution of water has been for years a common lecture-table experiment for illustrating the composition of water and the chemical action of the electric current: but it is only recently that this method has been applied upon an industrial scale for the commercial production of oxygen and hydrogen. Many forms of apparatus for decomposing water by aid of the electric current, and for collecting the gases liberated at the positive and negative poles, have been designed and patented; but the general principle of the process and design is common in all cases. In the majority of instances, a 10 to 20 per cent. solution of sodium hydrate is employed as electrolyte, with iron as electrode material. Incomplete sheet-iron partition walls or diaphragms separate the anode and cathode compartments of the cell, and the depth of these is so arranged that they effectually prevent admixture of the hydrogen and oxygen liberated at the cathode and anode respectively, while permitting the current to travel round them. The E.M.F. employed with such a cell must, of course, be carefully regulated, and should not exceed 2·4 volts, otherwise these incomplete diaphragms would function as secondary electrodes, the current would pass through instead of round them, and explosive gas-mixtures would be produced in each division of the cell. The iron walls of the outer vessel in this design of cell are usually employed as cathode, while a nickel or iron plate serves as anode. The *Garuti*, *Siemens and Halske*, *Oerlikon*, and *Schuckert* cells are of this type.

In the *Schoop* cell a dilute sulphuric acid solution is employed as electrolyte, and this necessitates lead being used as material for every part of the cell. Fig. 1 is a view of a series of Schoop cells for hydrogen and oxygen production, installed at Cologne, in Germany. The vessels on the left are the gasholders for storing the oxygen and hydrogen produced by the apparatus, that for hydrogen being the larger of the two.

The yield of oxygen and hydrogen with these forms of apparatus varies from 225 litres to 252 litres per k.w. hour, two-thirds of this volume being hydrogen. The cost of running the cells is low, since they require little attention, and the caustic soda or sulphuric acid used as electrolyte is continuously regenerated, only the water being decomposed. As regards cost, a Schuckert installation at Hanau, in Germany, is stated to yield 100,000 litres of oxygen and 200,000 litres of hydrogen per twenty-four hours, and the running costs amount to £6. 10*s*. per day. By this plant 60 litres of oxygen and 120 litres of hydrogen are therefore produced

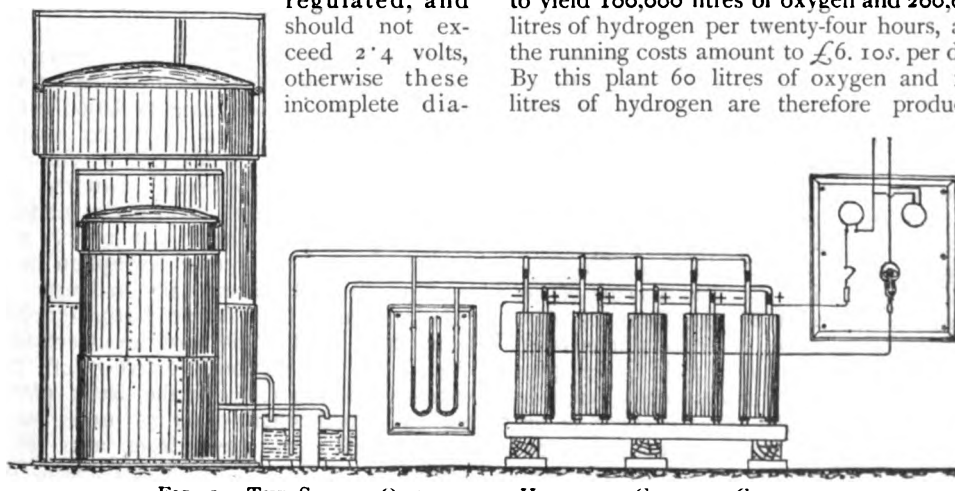

FIG. 1.—THE SCHOOP OXYGEN AND HYDROGEN CELL, AT COLOGNE.

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for 1*d*. Installations of this type in connection with other industries have been erected and worked at Tivoli, Rome, Milan, Zurich, Lucerne, Cologne, Hanau, Brussels, Toulouse, Oloron Ste. Marie, Montbard, and Paris; and, in addition to these, the balloon engineering corps of the English, German, and Italian armies have their own installations for preparing the hydrogen gas required for balloon purposes.

The applications of the gases are varied, but in many cases, as at Hanau and Cologne, the oxygen and hydrogen are utilised in a special form of blowpipe for heating purposes; and many storage cell and accumulator factories are now equipped with this apparatus for making the joints in the lead cells and plates.

The industry is, therefore, one of the most successful and promising of the minor electro-chemical industries.

Ozone.

It has long been known that the curious smell observed when working the old form of electrostatic machines was due to the formation of ozone, and that this was produced by the passage of the silent electric discharge from the collecting brushes and terminals of the machine, through dry air.

This method of ozone formation has now been applied to its production upon a large scale for industrial purposes; the required current pressure (5,000–20,000 volts) being obtained by the use of large induction coils, or by transformers worked in connection with an alternating current supply from the mains. A large number of ozonisers have been patented, the general principle being to use glass as dielectric between two metal plates or tubes; and to allow dry air to pass over or between the two electrodes while the silent electric discharge occurs. Sparking cannot be permitted, since it decomposes the ozone already formed; and the distinctive feature of the various patents taken out for ozonisers lies in the methods and devices adopted for minimising or avoiding this danger. Fig. 2 is a sectional drawing of the latest Siemens and Halske form of tube ozoniser, E being the outer metallic coating, D the inner metal tube, and C the glass dielectric. The air enters below, and on passing up the annular space between D and C, a portion of the oxygen is converted into ozone by the discharge occurring between the two electrodes. The outer tubes are surrounded by water to promote cooling, and all the outside parts of the apparatus are kept at earth potential, to minimise risks from the high potential employed. The Andreoli, Elworthy, Marmier-Abraham, Otto, Yarnold, and Vosmaer-Lebret are other forms of ozonisers, which have received trial upon an industrial scale. The production with these forms of apparatus varies from 20 to 150 grams of ozone per k.w. hour. As regards utilisation of the ozonised air produced, no great success has yet been attained in any direction, and most of the attempts to apply ozone in the arts and industries are still to be regarded as experimental in character. Ozone is, of course, a most efficient bleaching and oxidising agent; but other agents for effecting oxidation in the chemical industries exist, and are usually preferred since they are less costly; chlorine being that usually employed. Latterly, the application of ozonised air to water purification has received much attention, and experimental plants of this description have been erected at Paris and Lille in France, at Schiedam in Holland, and at Martinikenfelde, Schierstein, and Paderborn in Germany. Fig. 3 is a sectional drawing of the water-sterilisation tower at the latter place. Similar experimental trials of ozone as a water purification agent have also been carried out at Lea Bridge, near London, but no very trustworthy figures, showing the

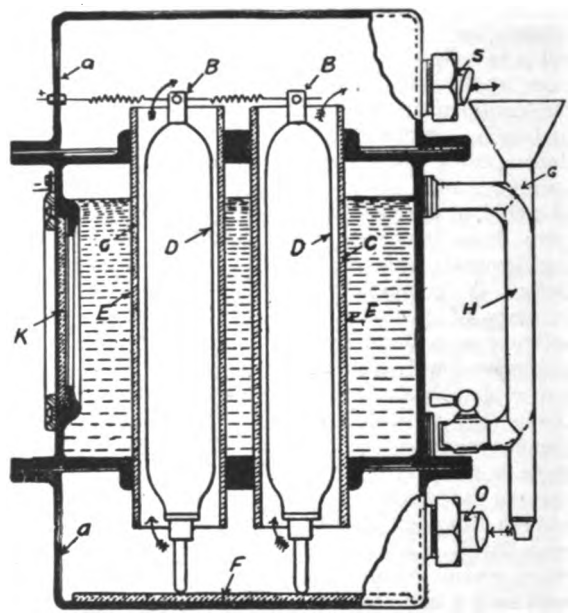

FIG. 2.—THE SIEMENS AND HALSKE TUBE OZONISER.

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economic results of any of these trials, have yet been published. The general opinion is that ozone as a water-purifying agent will prove too costly for adoption, excepting in those cases where there is special need for absolute sterilisation of the water supply. This was the cause of its adoption at Lille, which was some years ago subjected to an epidemic of typhoid fever that was traced to the water supply. Other applications of ozonised air are for the bleaching of oils and fats, the preservation of fruit and food, and for the production of certain organic chemicals. So far, the most notable success has been achieved in the manufacture of vanillin and heliotropine at Courbevoie, near Paris; but trials which may lead to important industrial development, in connection with the other applications named above, are now proceeding in this country. The ozone industry may therefore still develop into one of some magnitude and importance.

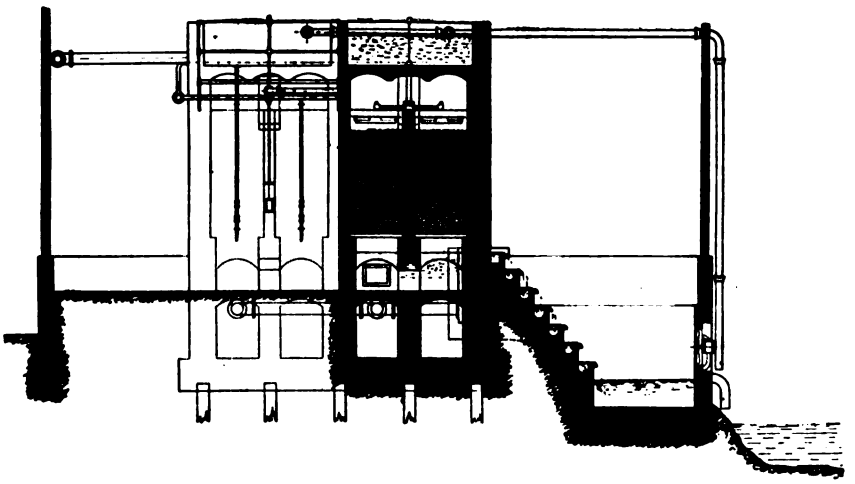

FIG. 3.—WATER-STERILISING TOWER AT PADERBORN, GERMANY.

Nitric Acid and Cyanides.

One of the latest proposals for the application of electricity in the chemical industry is to employ it for the fixation of the nitrogen of the air, either in the form of nitric acid, nitrates, or cyanides. An experimental plant for obtaining nitric acid by aid of the electric spark discharge has been operated for over a year at Niagara Falls, the process employed being that patented by Bradley and Lovejoy. In this experimental plant dry air is submitted to the action of a rapid succession of spark discharges in a special form of apparatus; a direct current of from 8,000 to 15,000 volts potential, and 138 arcs, breaking and making 3,000 times per minute, is employed. The air, after passing through the apparatus, is said to contain 2·5 per cent. of nitrogen oxides; and a company named "The Atmospheric Products Company" has been formed to exploit the patents. The fundamental idea of the process is not new: McDougal and Howles in this country, and Kowalski and Moscicki in Germany, have experimented upon the same reaction, and have published valuable figures and data obtained in their researches.

The two foreign investigators have also patented their method of applying the principle of spark discharges to nitric acid production; and their process is believed to be receiving trial upon an industrial scale at the factory of the *Société de l'Acide Nitrique*, at Fribourg, in Switzerland. Muthmann and Hofer at Munich, and Dr. von Lepel in Vienna, are also experimenting with similar processes, and have obtained instructive results. The writer is doubtful whether any commercially successful process of nitric acid production will result from these trials. Volney has shown that the electric spark decomposes nitric acid and the oxides of nitrogen, and that the reaction is, therefore, a reversible one; while Haber has stated, as the result of personal observation, that the production of acid above 55 per cent. HNO_3 is impossible by the process worked at Niagara Falls.

The manufacture of nitric acid by aid of the electric current from the oxygen and nitrogen of the air, therefore, will be probably

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relegated to the growing list of electro-chemical processes which are theoretically possible, but are not, under the present industrial conditions, practicable or of economic value.

With regard to the formation of cyanides, the processes are equally tentative and experimental; and the possibility of competing with the usual chemical methods of cyanide manufacture is still unproved.

One process for fixing atmospheric nitrogen in the CN form of combination is to heat a mixture of lime or chalk and charcoal to a temperature of 2,000° C. in an electric furnace, and to lead air or nitrogen over the heated mass. A product known as "calcium cyanamide" is obtained, and this may be utilised to form potassium cyanide by double decomposition, or it may be directly employed as an artificial manure and as a substitute for nitrate of soda or sulphate of ammonia in agriculture. Under the name of "Kalk-sticktoff" the product is, in fact, reported to be now manufactured and sold for this latter purpose in Germany.

Another process for obtaining nitrogen in combined form from the air has been patented by Chalmot, and is being tried experimentally in the United States. Rutile, a mineral containing chiefly titanium oxide, is heated with excess of carbon in an electric furnace, and nitrogen is forced downwards through the heated mass. A nitride of titanium is produced, and if steam be blown through the mass of ore and coke while still in the heated state, ammonia (NH_3) will be produced. The inventor states that the process can be made a continuous one, and that the oxides of calcium, barium, or aluminium may be employed in place of titanium oxide.

Another method of cyanide production in the electric furnace, which is now receiving trial in the United States, has been patented by the Ampere Electro-Chemical Company of Niagara Falls, in America and Germany. A carbide is first formed in the usual manner, and this is heated with coarsely powdered coke, in order to obtain a porous product on cooling. Nitrogen is then passed through the porous mass as it cools, and combination between the carbide and gas under these conditions is said to occur, barium carbide giving the best yield of cyanide.

Readman, in English Patent No. 6621 of 1894, has also described a process for producing ferro-cyanides in the electric furnace, which is somewhat similar in principle. In this case, a mixture of oxides and carbonates of the alkaline earth metals with iron oxide was heated with carbon in an electric furnace, and nitrogen or generator gas was allowed to pass through or over the heated mass. This process was exploited by a company in Scotland some years ago, but the writer has not been able to obtain any trustworthy information relating to its present position, and the probability is that the works near Edinburgh have not proved a financial success.

These experiments and researches upon the fixation of atmosphere nitrogen have been described in some detail, not on account of their present industrial value, but by reason of their significance for future generations. At present the nitrogen required by the soil for the growth of many crops is supplied, not by natural manures, but by the two chemicals nitrate of soda (Chili saltpetre) and sulphate of ammonia. The dependence of modern farmers upon these two chemicals is also increasing every year. Sir William Crookes, in his Presidential Address before the British Association at Bristol in 1898, pointed out that this position could not continue indefinitely, and that when the deposits of sodium nitrate in South America had been exhausted, agriculturists would have to find another source for the nitrogen required by their crops. Sir William Crookes then went on to state that it would be well to face this problem before the contingency arrived, and referred to experiments by Lord Rayleigh and to the possibilities of the electric furnace in this connection. It is interesting to note that his prophetic utterance is in course of fulfilment, though as yet the industrial success of these new processes is not assured. When other sources of nitrogen fail, however, there is little doubt that the almost inexhaustible supply contained in the air will be tapped, and that either the electrical processes named above, or some modified form of these, will supply the world with the nitrates necessary for the sustenance and growth of those cereal crops upon which the continued existence of the human race depends.

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SOME COMMON DEFECTS IN TIMBER AND THEIR CAUSES.

By HAROLD BUSBRIDGE.

MANY features of wood, which are regarded as defects by the timber merchant, are the necessary result of the life of the tree, and hence timber could not be grown without them. Such defects may, therefore, be termed "essential," or unavoidable; although these can never be entirely eliminated, it is nevertheless possible by proper treatment during growth to reduce some of them to a minimum. By careful selection of the wood from the best parts of the log after felling, we may further avoid some defects, whilst others may be entirely removed.

Let us, then, consider first those essential parts of a tree which are generally looked upon as blemishes by those who make use of timber for structural and other purposes.

1. The medulla, or pith, forms the axis of every tree trunk and of every branch. It is formed at the very earliest stage of growth, and when very soft, as is sometimes the case

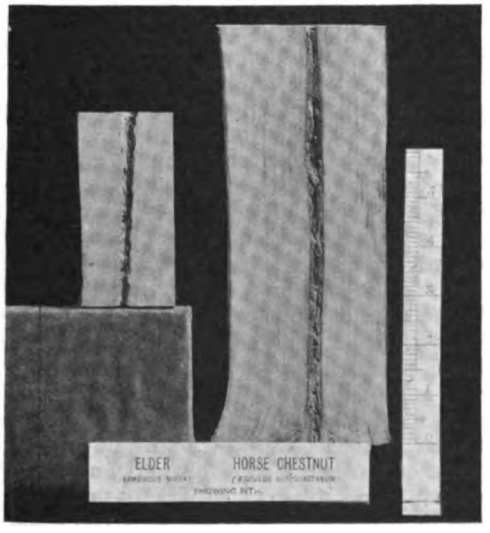

FIG. 1.—LONGITUDINAL SECTIONS OF ELDER AND HORSE-CHESTNUT, SHOWING MEDULLA.

—in horse-chestnut and in elder, for instance (Fig. 1)—it renders the centre of the log unsound, so that baulks, deals, or battens which contain the centre are defective.

Pitch pine and inferior yellow deal are often found to have soft and defective pith, thus reducing their market value to a considerable extent; but, as a rule, most timbers

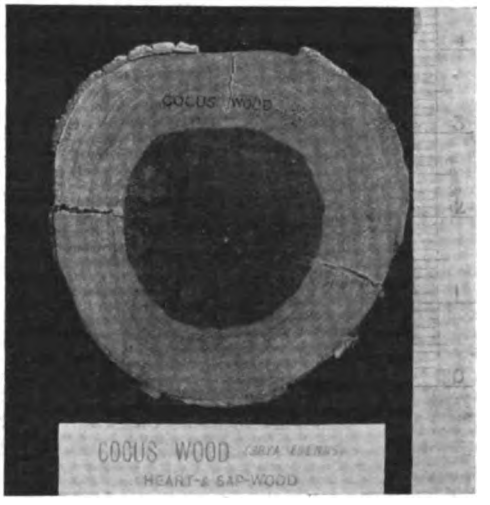

FIG. 2.—TO ILLUSTRATE DISTINCTION BETWEEN "SAPWOOD" AND "HEARTWOOD."

can easily be obtained with perfectly sound centres.

2. Most architects' and engineers' specifications require that timber shall be free from sap. Now in every tree the last few, and therefore outermost, annual rings formed consist entirely of sapwood, and it is by means of these outer rings that the branches, leaves, and fruit are supplied with nourishment from the soil upon which the tree grows. The only way, therefore, to obtain wood free from sap is to cut away all the outer rings which form the sapwood. It is well known that in nearly all timbers the sapwood, or "alburnum," is softer, contains more moisture, shrinks more, is less durable, and is more liable to the attacks of parasitic plants and insects than the "duramen" or heartwood. Fortunately, sapwood can generally be easily recognised by its lighter colour (see Fig. 2); whilst in the case of yellow deal and other coniferous timber, it is often stained of a blue or greenish colour by the water in which it is floated down to the port of shipment. Large and well-matured trees always have a smaller

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proportion of sap than young trees; hence it is always best to select for felling only those trees which have reached maturity. In dark-coloured woods the sapwood is often very light in colour. Thus the sapwood of ebony is nearly white; and of cocus-wood, of which the heartwood is very dark brown, the sapwood is pale yellow (Fig. 2).

3. Knots are always regarded as troublesome, especially by those who have to work the material; and when the grain of the wood is exposed to view in the finished work, they are considered to be serious defects if either large or numerous.

When it is remembered that they really mark the origins of branches, it will at once be understood that to have wood free from knots, it will be necessary to grow trees with stems free from branches. This, of course, is much easier to do in some kinds of wood than in others. When trees are grown close together in plantations, they tend to run straight up to a considerable height before throwing out branches, and hence their wood is more free from knots than that of similar trees grown in the open. In other cases, the stems may be kept free from large knots by lopping off, when quite young, all branches and shoots, until the head of the trunk is reached, where the principal branches separate.

Naturally the top ends of all logs are apt to have larger and more numerous knots than the butt ends. To get the best and straightest-grained timber, therefore, one always prefers the butt to the top end.

In most, if not all, coniferous timber, the knots run right to the centre of the main

FIG. 3.—KNOTS IN YELLOW DEAL.

FIG. 4.—DEAD KNOT.

stem; and in some cases, such as in yellow deal (*Pinus Sylvestris*), the knots occur in regular groups of about five, at intervals throughout the length of the stem. These groups are termed "nodes," and often give a ready means of distinguishing the timber from other kinds, by the regular groups of knots which appear on the face of a board or plank cut from such a tree. Fig. 3 gives a cross section with a typical group of knots as they occur in yellow deal.

In dealing with boards and planks cut from coniferous trees, one often meets with what are known as "dead" or "loose" knots. Such knots are not firmly united to the adjoining wood, but are often surrounded by a ring of dead bark, and can easily be separated—in fact, they often drop out of their own accord. They are caused by the branch they represent dying, or having been broken off, whilst the parent stem was still growing. Part of the old branch thus becomes embedded in the new wood, and having no vitality, the knot shrinks, and thus becomes loose. Fig. 4 represents a dead knot occurring in a piece of American yellow pine.

A second group of defects met with in timber includes those which are not essential parts of a healthy tree, but are formed by mishap or accident during its growth. They are always developed before the tree is felled, and may be regarded as either wholly or partially avoidable, if proper attention is paid to the growing tree.

Of this class, perhaps, the several kinds of "shake" should receive our first attention; not only because they are frequently met with in the ordinary timber of commerce,

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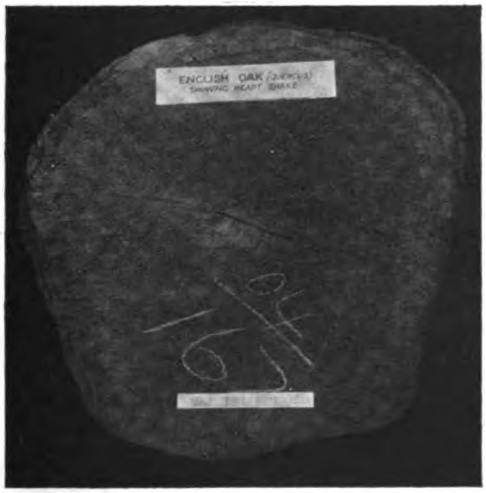

FIG. 5.—HEARTSHAKE.

but because, more than almost any other defect, they ruin the material in which they occur.

Heartshake (Fig. 5), for instance, is met with in nearly every species of timber, although certain kinds, such as Indian teak and pitch pine, are more liable to it than most other woods. This defect is common to dicotyledonous trees as well as to the conifers, and it appears in trees grown in all kinds of soil and in many different climates.

When found, it seems to be an indication of incipient decay consequent upon old age. It generally consists of a single crack extending across the centre of the tree and diminishing in width towards the circumference.

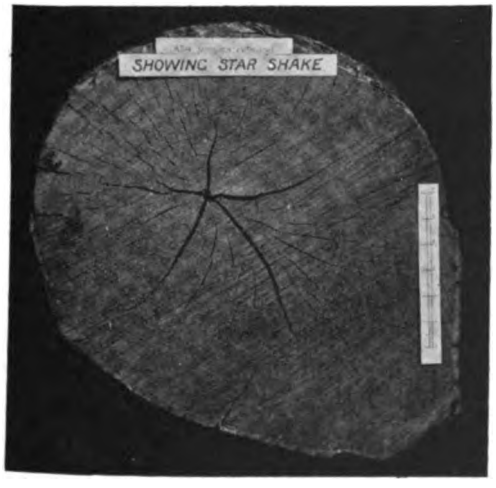

FIG. 6.—STARSHAKE (ASH, *Fraxinus excelsior*).

Sometimes two such cracks cross each other nearly at right angles, but in all cases the defect may be distinguished from side shake by the cleft being widest at the pith or centre. If the grain of the tree is pretty straight, and the clefts not very extensive, this defect does not injure the timber seriously, since by causing the saw cuts to follow the direction of the shake, fairly sound boards or scantling may be obtained. The worst form of the defect happens when the grain of the tree is twisted, as in Fig. 12, so that, perhaps, a single cleft may twist through 90° in the length of the log. In such a case it is practically impossible to obtain from the tree a single wide board entirely free from shake.

If, instead of one or two, we find several shakes radiating from the centre, as in Fig. 6, we have what is termed a "starshake."

This may be regarded as an aggravated and more extended form of the fault last

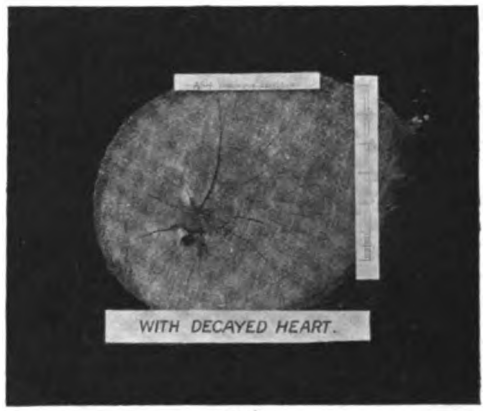

FIG. 7.
DECAYED HEART (ASH, *Fraxinus excelsior*).

described, and is found in trees of all ages and conditions of growth. In extreme cases, the clefts reach almost or quite to the circumference of the log, and sometimes they are so numerous and so extensive as to render the log quite unfit for conversion into smaller scantling or into boards. Heartshake and starshake generally indicate that decay has set in, owing to air and moisture having gained access to the centre of the tree. This may happen after the loss either of a branch or a root, if the wound is not properly protected.

When once oxygen gains access to wood in a moist condition, oxidation of the wood substance sets in, and the inevitable shrinkage which follows chemical decomposition sufficiently accounts for the appearance of the clefts.

Closely related to the defects last considered

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are the decayed hearts (Fig. 7), of which numerous examples must be familiar to all those having any acquaintance with our parks and woods.

Sometimes logs are found in which heartshake and starshake are accompanied by partial decay starting from the pith; and since it is almost impossible to arrest decay when once begun, the originally sound tree is certain to develop into a hollow one.

The sap necessary to the life of the tree flows exclusively through the alburnum or sapwood, and hence the whole of the heartwood may decay without seriously impairing the vitality of the tree. When decay has advanced so far that most of the heartwood is affected, the tree may be regarded as practically worthless for constructive purposes, except perhaps in the case of common elm, of which the sapwood is said to be as durable as its heartwood.

The defect known as cupshake, ringshake, or shellshake (Fig. 8) is of a different nature, and is frequently met with in many kinds of wood. It consists in a partial or entire separation of two consecutive annual rings, and appears on a cross section as one or more splits running concentrically around the log.

Sometimes such shakes jump radially across

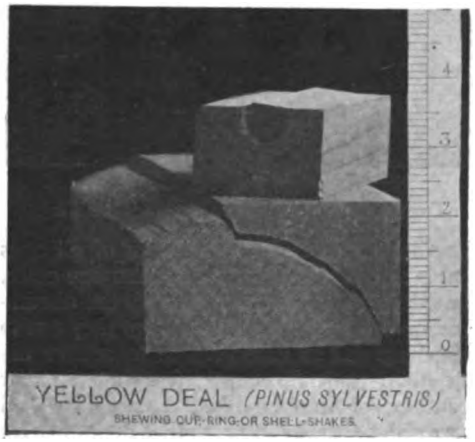

FIG. 8.—CUP, RING, OR SHELLSHAKES.

several rings, and continue their course in a wider circle. This defect occurs in perfectly sound and healthy looking trees, and is frequently met with in yellow deal from Archangel and elsewhere; also in Virginian pitch pine, and in lignum vitæ from San Domingo.

Opinions differ as to its cause, some attributing it to forest fires scorching the base of the tree, and so preventing the perfect cohesion of the next-formed annual ring; whilst others consider that severe frosts have a similar effect. Possibly, too, the effect of high winds upon tall soft-wood trees, in bending them, may cause the shearing stresses induced between the annual rings to produce ruptures which appear in the timber as already described.

An "upset," or, as it may be termed, a

FIG. 9.—TRANSVERSE SHAKE.

"transverse shake" (Fig. 9) is much more rarely met with, and, so far as I know, is found exclusively in foreign hard-woods, grown chiefly in tropical or sub-tropical climates. It consists of a complete severance of the longitudinal fibres of the tree in certain spots; but, as a rule, the defect is not very extensive. Mahogany and teak are often affected by it, and boards containing such upsets will break off suddenly without warning. I have heard workmen attribute this defect to the effects of lightning; but this, to me, seems very improbable. A much more reasonable explanation is that such trees, during their lifetime, have been exposed to severe hurricanes, which, although of insufficient power to uproot the tree, have nevertheless succeeded in permanently injuring the trunk by partially severing the fibres, either by tension on the windward side, or crushing by compression on the leeward side.

After the gale, the tree has had sufficient vitality to continue its growth, and so enfold its crippled stem in a new sheath of sound wood.

Fig. 10 represents decayed or "druxy"

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FIG. 10.—"DRUXY" KNOTS.

knots. Sometimes such knots are met with embedded in fairly sound wood, but in most cases, the effects of the decay run far down into the parent stem, whilst sometimes a tree may be quite ruined by one. In fact, heart-shake, starshake, and decayed heart often owe their origin to a decayed knot.

When a branch is severed from the parent stem the wound is gradually covered by successive annual rings of wood from the trunk, each overlapping the last formed ring, until the wound is healed. Several years must, therefore, elapse before the wound left by the removal of even a small branch can be covered over by new wood, more time being required in proportion to the size of the wound. During this time decay may set in over the exposed surface, by the action of moist air alone; but it is more often hastened by the attacks of parasitic insects, by fungi, and by bacteria.

When this happens the knot, instead of remaining sound, becomes "druxy," and often the wood around it is completely spoiled.

A "rind gall" (Fig. 11) owes its origin to the partial removal of bark from the trunk of a growing tree. This may be due to wilful mischief on the part of boys or others, or to the action of certain animals in rubbing their horns or gnawing off the bark with their teeth.

Since deposits of new wood can be formed only beneath the protective bark, all growth ceases over those areas which have been denuded of bark. Nature, however, immediately sets to work to repair the damage. The next formed annual ring overlaps the edge of the wound on all sides, so as to reduce its area. The succeeding ring overlaps the last still further, and so on, until after a certain number of years the bared trunk is completely covered with new wood, all enclosed within a protective envelope of bark. Of course the success of Nature's effort, from the practical man's point of view, depends on whether or not decay has set in before the wound has been covered with new wood. In the former case, the wood remains sound, and no injury results to the timber, whilst in the latter case the damage may be serious.

Many trees have their vertical elements arranged in a slightly spiral direction, instead of growing parallel to the axis of the trunk. The cause of this peculiarity does not seem to be fully known, although several theories have been advanced to account for it. It has been thought that when a tree is not equally exposed to sunlight on all sides, it may rotate upon its axis in an effort to give its sheltered sides more sun, thus producing a twisted grain. Another theory is that the prevailing winds, acting upon any exceptionally large branch, exercise a turning effect upon the trunk, the result being the twisted grain already remarked. Boards and planks cut from such trees prove unusually troublesome to the builder, since they not only contain a great deal of "cross grain," but in seasoning the grain is very apt to untwist, thus giving

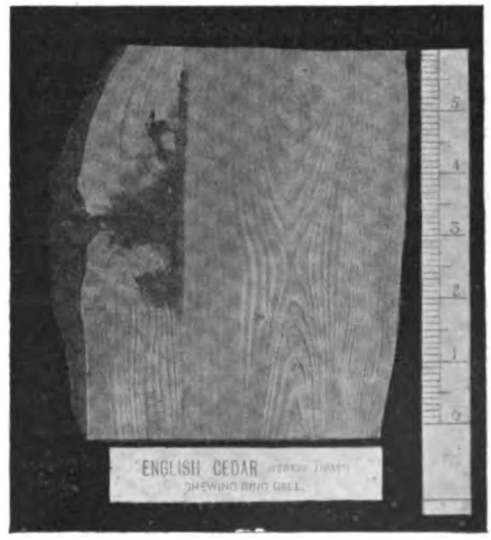

FIG. 11. RIND GALL.

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rise to excessive waste in the operation of truing up. Not only so, but any shakes which may occur, as in the pole shown in Fig. 12, follow the direction of the grain, and often ruin the whole log. The warped doors and framing so frequently noticed in buildings may generally be traced to timber affected with this defect. The drawing board shown

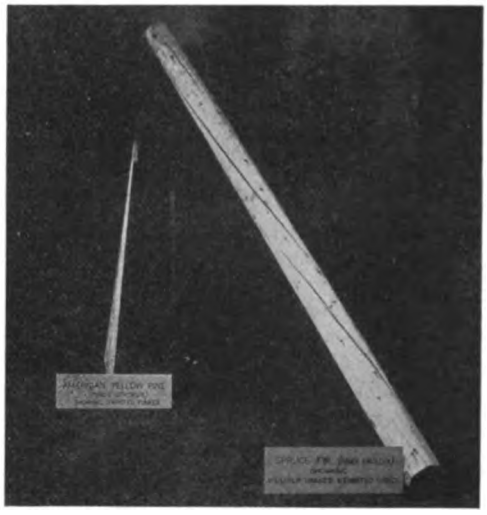

FIG 12.—WEATHER SHAKES AND TWISTED GRAIN.

on the left-hand side of Fig. 12 affords a case is point.

Some trees have grown from saplings of which the stems were originally very crooked. They tend to straighten themselves with advancing age, by adding more wood on the concave sides of the bends, so that ultimately a fairly straight trunk may be produced. Boards and planks cut from such trees sometimes exhibit the defect known as "wandering heart." They contain a large amount of cross-grain, besides which, in seasoning, they warp very unequally, and sometimes curve in opposite directions in different parts of their length. The reason for this will be apparent when it is remembered that a plank cut from the centre of the log may have the pith considerably below its surface in some places, whilst in others it would be considerably above it. This defect is most often met with, and is most troublesome, in English oak, elm and other hardwoods which have an irregular habit of growth.

One other defect known as "inbark" (Fig. 13) may be referred to. It is caused by the inclusion of portions of the external bark within sound wood.

It often occurs where branches separate from the trunk, and is caused by their growing together in the hollow of the fork. Some trees are more liable to this defect than others, and it proves especially troublesome in some of the fancy hardwoods, such as

FIG. 13.—"INBARK."

burr walnut, employed by the cabinet-maker, in which a small piece of dead bark may spoil an otherwise valuable log. Generally speaking, in timbers used constructively it is seldom found to any serious extent.

The defects which originate after timber has been felled must be dealt with in another article.

Lantern Slides of Figs. 1, 2, 3, 4, 8, 9, 10, 11, 12, *can be obtained from Messrs. Newton & Co. The author is indebted to the Director of the Natural History Museum, South Kensington, for permission to photograph the remaining sections.*

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MORTARS AND CEMENTS.

By BRYSSON CUNNINGHAM, B.E., Assoc.M.Inst.C.E.

MORTAR is one of the most familiar and important substances in the domain of technical science. It has a history dating back to remote ages, possibly to pre-historic times. Probably the earliest mention of it is in Sacred Writ, in connection with the building of the Tower of Babel. It must obviously, however, have been known and in existence for some time prior to the date of that renowned instance of engineering enterprise.

It is a substance commonplace enough, compounded of common materials—lime, sand and water; yet, in the eyes of the chemist, it is dignified by the wonderful metamorphoses which it undergoes throughout the various stages of its manufacture—subtle, mysterious, inexplicable almost. Furthermore, its utility is unquestionable and far-reaching. The builder, the architect and the civil engineer would be at a loss to replace the services which it renders to them. Cathedrals and bridges, factories, dwelling-houses and public buildings alike, owe their very existence to its invaluable qualities.

Technically, mortars are divided into two varieties: one in which pure lime forms the cohesive agency, and the other in which an argillo-calcareous compound is substituted for pure lime. There is a marked difference in their respective properties, and though one or two intermediate gradations containing varying proportions of both ingredients have caused some slight confusion of nomenclature, yet it may be said that, broadly speaking, the former variety is *mortar* in the ordinary acceptation of the term, while the latter is distinguishable as *cement mortar*.

By far the most important constituent of mortar is lime, a substance known to the chemist as protoxide of calcium (CaO). It occurs most commonly in nature in conjunction with a gas, carbonic acid or carbon dioxide (CO_2), the two forming carbonate of calcium ($CaCO_3$) or limestone. When carbonate of calcium is ignited at a white heat, it loses its carbon dioxide, which passes off in the gaseous form, leaving protoxide of calcium, or caustic lime, commonly known as quicklime.

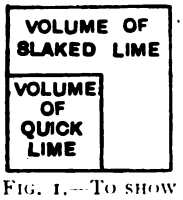

FIG. 1.—TO SHOW THE RELATIVE VOLUMES OF QUICK AND SLAKED LIME.

In chemical symbols, the change may be expressed thus:

Calcium Carbonate.		Protoxide of Calcium.		Carbon Dioxide.
$CaCO_3$	=	CaO	+	CO_2

The operation of calcination, or burning, causes the limestone to lose a considerable portion of its weight. One hundred parts of carbonate of calcium will only produce fifty-six parts of the protoxide. This is due, of course, to the loss of the gas. Becoming porous, the lime undergoes practically no diminution in volume.

Quicklime is a pure white, or very light brown substance, somewhat friable and incohesive. It possesses a great avidity for water. If this last be added freely, the lime expands and decrepitates into a fine powder, giving off great heat during the process, and ultimately developing, with the aid of sufficient water, into a paste of the consistency of soft butter. In this condition it is known as calcic hydrate or, in common parlance, slaked lime. The chemical equation is

Calcic oxide.		Water.		Calcic Hydrate.
CaO	+	H_2O	=	CaH_2O_2

The quantity of water absorbed during the slaking process is about one-third of the volume of quicklime, some of the water being evaporated at the high temperature (150° C.) which is developed. An additional and equal quantity of water is required to reduce the lime to the state of pulp in which it is used. The volume of calcic hydrate in the form of powder is some three times as great as the volume of the original carbonate from which it was produced. Fig. 1 illustrates this change of bulk graphically.

The calcic hydrate has characteristics which are quite the reverse of those possessed by the oxide: it has lost its affinity for water and regained an affinity for carbonic acid gas. This striking metamorphosis results in its becoming a most valuable agency in building construction. The hydrate re-absorbs from the atmosphere some of the carbonic acid gas which it had previously lost, and, in so doing, parts with its water. This development is called *setting*, and is quite distinct from mere drying, or the evaporation of moisture. Were the action perfectly efficient, it is

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obvious that the carbonate would once more be created, and the cycle of operations would be complete. But this is not the case; though the process of absorption is fairly quick and well marked at first, later it falls off in intensity, and the full equivalent is never realised. In fact, pure calcic hydrate is but indifferently situated for accomplishing the ideal task. The material is not sufficiently porous to allow the carbon dioxide to penetrate into the heart of its mass, and the consequence is that a crust is formed on the outside, effectually cutting off the remainder from contact with the atmosphere. Quicklime may thus be left for a very long period without any perceptible hardening of its internal particles.

Another characteristic of quicklime is its shrinkage or diminution in volume. Some such tendency is manifestly to be expected after its previous expansion. The contraction is very marked, taking place to the extent of 40 or 50 per cent.

These two features —imperfect setting and shrinkage—constitute grave disadvantages to the general employment of pure lime for structural operations, especially if exposed to atmospheric influence. The use for external work, of mortar made from lime, though not uncommon, is greatly to be deprecated. Owing to its inherent weakness, it should be confined to internal situations, and used for decorative and ornamental purposes only.

To some slight extent, a corrective of the evils above mentioned is found in sand. Mixed with slaked lime in varying proportions, its porosity enables the carbonic acid gas to penetrate further into the mass; and its own unalterability reduces the proportion of shrinkage, while at the same time an economy in cost is effected. Furthermore, it improves the properties of the lime, since it is found that there is greater adhesion between the sand and the lime than there is cohesion in the lime.

Sand for mortar-making purposes should be essentially clean, sharp, and not too fine. Admixture with particles of earth, loam, clay, or other foreign matter, in any shape or form, is harmful. If the sand has been in contact with such impurities, it should be washed—that is, sifted into running water and afterwards allowed to settle. Too much importance cannot be attached to cleanliness. Unless the sand be pure, the mortar will be weak and untrustworthy. On this account, mortar for building purposes is placed out of contact with the ground on a "banker," or floor of wooden deals laid temporarily, or in a tub, or upon some suitably prepared surface.

Sand is obtained from three sources—from pits, river banks, and seashores—but pit sand is preferable to both seashore and river sand. The grains in the first are sharp and angular; in the other two cases, they are more or less rounded by attrition. Sea sand, moreover, has the serious drawback of being impregnated with salt; this renders it hygroscopic, and mortar made from it is always damp. In most cases there results an unsightly floury efflorescence upon the walls and other parts of a building in which it is used. Moreover, dampness retards the setting of pure slaked lime.

Whatever kind of sand be used, the incorporation of the two materials should be as thorough and intimate as possible. Every facet of the sand grains should be covered by a film of lime, and this can only be effected by prolonged manipulation. Hand mixing may suffice in certain instances where strength is not an essential matter, but the use of a mortar mill is infinitely to be preferred. The ingredients should be put into the pan in the form of slurry, and passed under the heavy revolving wheels for a period of from 20 to 30 minutes. Care must be taken neither to underdo nor overdo the process. Excessive grinding will cause too great comminution of the particles.

Thus far we have practically only dealt with lime which is chemically pure, or "fat" lime, as it is termed by the builder. Such lime is produced from chalk, marble, and other pure carbonates of calcium. But there are many limestones in existence which yield a lime combined, in greater or less degree, with other ingredients. Sometimes these ingredients are of a negative character, such as silica in the form of sand, flinty particles, and grains of quartz. They do not, in themselves, affect or modify the slaking action, though they are impurities in the sense that they lower the strength of the lime by reducing its capacity for admixture with extraneous sand. Hence, the builder regards these limes as inferior substances, and dubs them "poor" limes. On the other hand, there are ingredients exerting a powerful constitutional influence, and the most remarkable of these is clay, which confers upon lime the valuable property of hydraulicity, or of hardening under water. Such clay-lime compounds form the class of hydraulic limes and cements.

Clay is a hydrated silicate of alumina—in simpler terms, a combination of silica,

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alumina and water; to produce hydraulicity, it must be in chemical combination, and not merely in a state of mechanical mixture with the lime. When this condition is fulfilled, the circumstances of calcination and hydration are very materially altered. In the former operation, not only is the carbonic acid expelled and calcic oxide formed, but calcic silicates and calcic aluminates are also produced, and according to the predominance of these latter constituents, the visible effects of slaking become less and less pronounced, disappearing altogether when no free lime is left. Up to this point, the lime is classified as more or less an hydraulic lime; beyond it, the lime becomes a cement.

Much, however, depends on the intensity of calcination. Limestones containing a large proportion of iron, potash, and soda, cannot be burned at a high temperature without incurring the risk of becoming an inert mass from fusion; whereas when the proportion of these ingredients is small, the temperature may be considerably raised with safety. Now the calcic silicates are formed at a comparatively low temperature and the aluminates at a comparatively high one. If, then, a limestone is of such a nature as to be susceptible of fusion, it can only be burnt at a moderate temperature; and in order to form a cement, it must contain a sufficiency of clay to provide the silica necessary to combine with all the lime: this is the basis of Roman cement. When, however, the temperature may be raised to a higher degree, a smaller proportion of clay will suffice, the excess of free lime from the first stage being absorbed in the succeeding aluminate compounds formed towards the close of the operation, and this is the constitution of Portland cement.* Roman cement nodules contain from 30 to 50 per cent. of clay; Portland cement clinker from 20 to 30 per cent. In each case, the ideal cement is that which is produced from quantities so balanced that there is neither excess of lime nor excess of clay for the particular system of calcination employed.

Cements containing a large proportion of clay set with considerable rapidity, but attain no great hardness. Those in which the percentage of clay is small set much more slowly, but are noted for their enormous ultimate strength. Both classes set better under water than in air.

Having briefly reviewed the chemical and theoretical aspect of the subject, it is desirable that we should now devote some attention to the adaptation of mortars and cements to practical ends.

Sand is generally added to chalk or fat lime in the proportion of three to one by volume. Theoretically, the best proportion would be that which made the cementing agency just as strong as the cemented material. In the case of fat lime, however, the strength of the strongest mortar which can be made is insignificant in comparison with the strength of brick or stone, and it matters comparatively little what proportion of sand is used. In fact, the larger the quantity of sand, the greater the porosity of the combination, with its attendant advantages. With the proportion stated above, the resistance to crushing will be perhaps $\frac{1}{20}$ that of a brick. If the unit be the cubic foot, about eight gallons of water will be required to be added, and the result will be slightly over 3 cubic feet of mortar. These quantities, however, are merely approximate, and much will depend on the freshness of the lime and the coarseness of the sand.

With hydraulic lime, a smaller proportion of sand is desirable: say two parts of sand to one of lime. About the same quantity of water will be required, but the resulting volume of mortar will be rather less.

A very valuable substitute for sand in mortar-making is to be found in ground ashes, when these are obtainable. An excellent proportion is $3\frac{1}{2}$ parts of hydraulic lime to $5\frac{1}{2}$ parts of ashes. Mortar made in this way gives exceedingly high results in the testing machine, as is evidenced in diagram Fig. 2. Noticeable also is the difference in the results, when the mortar is allowed to set under water and in air. In Fig. 3, the strength of the ash-mortar has not reached the value attained in Fig. 2, but it is considerably in excess of the standard set by the mortar in which one part of the ashes has been replaced by sand.

Though there are many varieties of cement on the market, the use of none is so universal as is the case with Portland cement. The manufacture of this commodity has attained extraordinary dimensions since the time when it was first discovered by Joseph Aspdin, a Leeds bricklayer, in 1824. It is a most valuable invention, and it fully deserves its world-wide reputation. As made at the present day, it results from an artificial

* The researches of Le Chatelier have demonstrated the fact that tricalcic silicate ($3\,CaO\,SiO_2$) is the constituent to which the hardening of Portland cement is essentially due, while all the calcic aluminates (of which there are three) contribute towards rapidity of setting.

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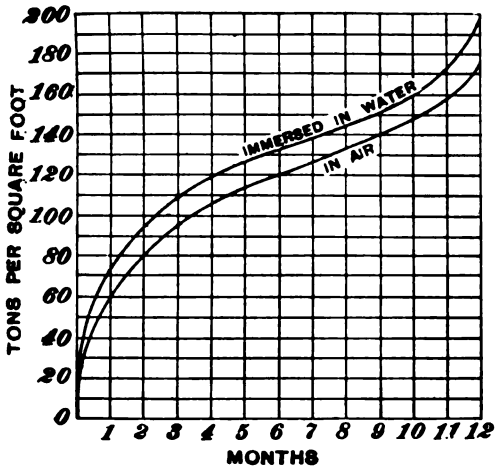

FIG. 2. — CURVES SHOWING RESISTANCE TO CRUSHING OF ASH-MORTAR, WHEN ALLOWED TO SET UNDER WATER AND IN AIR.

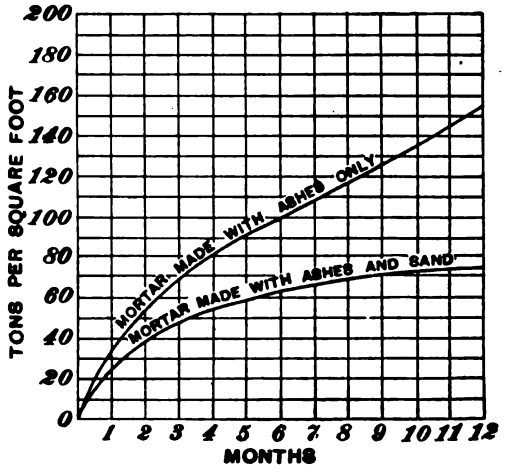

FIG. 3. — CURVES SHOWING RESISTANCE TO CRUSHING OF MORTAR MADE WITH ASHES, AND THAT MADE WITH ASHES AND SAND.

mixture of clay and lime in suitable proportions, either by means of the wet process, using chalk and clay and uniting them in water until they form a slurry of the consistency of cream, which is allowed to solidify; or by grinding limestone and shale to a fine powder and moistening: both processes being completed by burning the product in a kiln.

The average chemical composition of sound Portland cement, in round figures, is somewhat as follows:

	Per cent.
Lime	60
Silica	20
Alumina and oxide of iron	10
Magnesia, sulphur, alkalies, insoluble residue, and moisture	10

Of the last group, the insoluble residue should not exceed 1½ per cent., the magnesia 3 per cent., and the sulphur, in the form of sulphuric anhydride, 2½ per cent. Chemical analysis in the above form, however, is insufficient to determine the efficiency of a cement, for it takes no account of the degree of calcination, and it fails to distinguish between free and combined lime. This information, while known to the manufacturer, is not readily available to the consumer.

Accordingly, the engineer and the builder have to fall back upon certain physical tests, in order to assure themselves on the point. Four tests commend themselves more particularly to practical men: the first and most important of these relates to fineness of grinding. The reason for this is that the coarser particles of a badly ground cement become hydrated more gradually than the finer particles, and, consequently, they are liable to expand *in situ*, to the manifest detriment of the work. Moreover, fine cement will take a higher proportion of sand than coarse cement, and yet make a stronger mortar. Finally, the coarse particles are denser and add needlessly to the cost of carriage. Fineness is tested by means of sieves, the standard of which has been rising steadily for some time past. Several years ago, ten per cent. residue on a sieve with 1,600 meshes to the square inch, and twenty per cent. residue on a 2,500 mesh sieve would not have been considered excessive. Nowadays, requirements have risen as high as a residue not exceeding three per cent. on a 5,776 mesh sieve and 22½ per cent. on a 32,400 mesh sieve. The thickness of the wire is an important point: it should be one-half the size of the opening. The following table is based on this ratio:—

No. of wires per lin. inch.	No. of Meshes per sq. inch.	New Standard Wire Gauge.	Thickness of Wire.	Width of Opening.
			ins.	ins.
50 × 50	2,500	37	·0068	·0132
76 × 76	5,766	41	·0044	·0087
100 × 100	10,000	44	·0032	·0067
180 × 180	32,400	47½	·0018	·0037
200 × 200	40,000	48	·0016	·0034

It is, perhaps, desirable to point out that a finely ground cement may be obtained by supplying the mills with soft underburnt "clinker," which is inferior to that heavily burnt. To prevent this, the weight, or the

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specific gravity, of the cement is often specified. The former, which should lie between 110 and 115 lbs. per bushel, is not a very trustworthy guide, as the heavier cements are liable to overliming; moreover, cements decrease in weight as they grow old. The specific gravity should be between 3·1 and 3·15, but, even here, it is necessary to admit that the coarse particles have a higher density than the fine and more valuable "flour."

With good Portland cement, mixed neat, an average tensile strength of, at least, 500 lbs. per square inch should be obtained at the end of 28 days after mixing—one day in air and 27 immersed in water. It is usual also to require a minimum average strength of 400 lbs. at the end of seven days: in any case, there should be a gradual increase between the two dates, say, not less than 10 per cent. Testing is usually done in batches of six briquettes, and the figures given above will apply to the average of

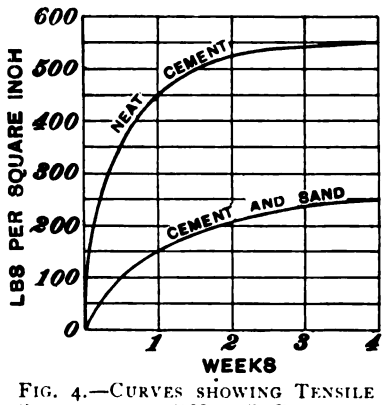

FIG. 4.—CURVES SHOWING TENSILE STRENGTH OF "NEAT" PORTLAND CEMENT, AND CEMENT MIXED WITH SAND.

each batch: considerable divergency in the results of individual samples is a most unsatisfactory feature, no matter how high the average may stand. It should not fail to be noted that the preparation of the specimen briquettes exercises considerable influence on the results obtained in the testing machine. Mechanical ramming materially increases the strength; but this is generally discountenanced, and the briquette moulds are understood to be filled carefully and compactly, without air holes, and also without undue pressure. Fresh water is used in mixing the paste.

In Germany, much importance is attached to a test in which the cement is mixed with standard sand, on the ground that the strength of the cement can only be properly estimated on this basis. Indeed, it has been found, that of two samples of cement, one finely and the other coarsely ground, the finer cement was the weaker of the two in the neat condition, but much the stronger in combination with sand. The test has latterly been introduced into this country with gradually increasing approval. The only difficulty is to obtain a sand of rigid uniformity. The criterion usually adopted is passage through a 400 mesh sieve and retention by a 900 mesh sieve. There is a sand found in the neighbourhood of Leighton Buzzard which satisfactorily answers the purpose, and it is generally specified. A briquette made with three parts of such sand to one part of cement should exhibit a tensile strength of, at least, 120 to 150 lbs. per square inch at the end of a week, with a regular increase to 250 lbs. at the end of a month. On the whole, the compressive strength of Portland cement closely approximates to ten times the tensile strength.

The third test of cement is in regard to time and duration of setting. Slowness in setting is generally indicative of strength. A quick-setting cement possibly contains an excess of clay, or some free lime, but fineness of grinding has an appreciable effect in accelerating the setting action. Setting is commonly gauged by a Vicat needle, weighing $2\frac{1}{2}$ lbs., having a flat end, in some cases $\frac{1}{16}$ inch and in others $\frac{1}{20}$ inch square. Failure of the needle to make any perceptible impression by its own weight upon the surface of the cement marks the official close of setting, which is generally specified to lie within five hours after mixing. Various foreign substances have been utilised to influence the rate of setting. Calcium sulphate, or gypsum, added to the cement during manufacture, retards the setting action, but any excess over 2 per cent. is harmful. Common soda accelerates hardening, but it weakens the cement, temporarily at any rate, as is evident from the diagram in Fig. 5. Bicarbonate of soda, on the other hand, retards the action considerably, as also do sugar, glycerine and salt, slightly.

No unimportant test is the last one on the list. If a cement fails to pass an examination for soundness, its other qualities cannot save it from rejection. A simple pat made of cement paste, say $\frac{1}{8}$ inch thick at the centre and as thin as possible at the edges, should exhibit no sign of cracking, blowing or expansion after 24 hours exposure to air or immersion in still water. Figs. 6 and 7

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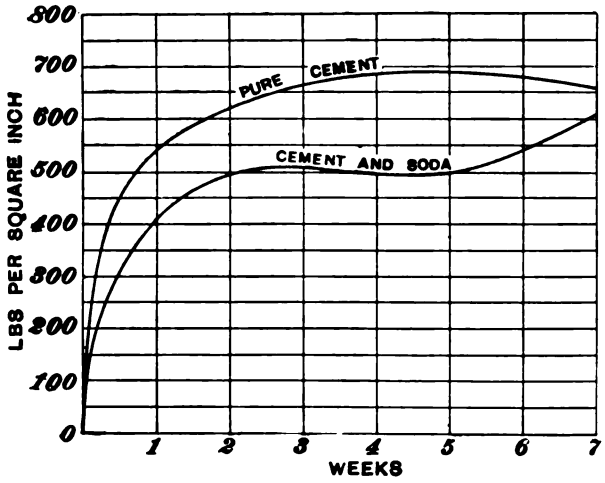

FIG. 5.—CURVES SHOWING THE EFFECT ON THE STRENGTH OF CEMENT DUE TO THE ADDITION OF SODA.

contrast the appearance of two pats after this test: the one sound and the other unsound. Another method is to use the Le Chatelier apparatus (Fig. 8). It consists of a small split cylinder of spring brass, having two long

FIG. 6.—APPEARANCE OF SOUND CEMENT.

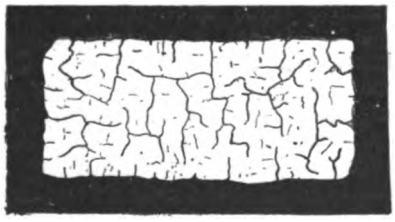

FIG. 7.—APPEARANCE OF UNSOUND CEMENT.

pointer arms. The mould is placed on a glass plate and filled with cement paste. A piece of glass is then placed on top and weighted, the whole being immersed in water for 24 hours. At the end of the time, the distance between the pointer ends *a*—*a* is measured and noted. The mould is replaced in cold water, which is raised to boiling point and maintained at that temperature for six hours. After being allowed to cool down, the distance between the pointer ends is again observed: any increase indicates expansion. The usual dimensions are: diameter of cylinder, 1·18 in.; length of arm from centre of cylinder to point, 6½ in.; maximum expansion permissible, 0·4 in.

Space will not permit of any lengthy consideration of the qualities of Roman cement. It is a natural product much inferior to Portland cement, and possessing only one-third of the strength of the latter. It is most appreciated in situations where rapid setting is essential, and no great strength is required. The cement contains a large proportion of clay (30 to 45 per cent.) and is burnt at a low temperature, losing thereby nearly one-third of its weight. Ten bushels of unburned stone will produce about eleven bushels of cement, weighing from 70 to 75 lbs. per bushel; in good cement, the higher limit should not be exceeded. Some five gallons of water per bushel are required for mixing, and the neat paste will set within ten or fifteen minutes after mixing. The average strength of sound briquettes is 100 lbs. per square inch at the end of seven days, and 150 lbs. per square inch at the end of a month. If mixed with sand, in a ratio which should never exceed 1½ parts of sand to 1 part of cement, the setting time is slightly prolonged and the ultimate strength greatly decreased. On account of its rapidity of action, Roman cement mortar should only be mixed in small quantities and used promptly.

There are many proprietary cements on the market: any consideration of these, however, must be deferred for the present.

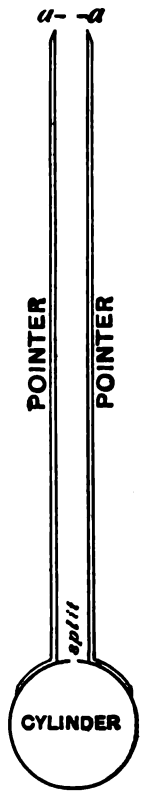

FIG. 8.—LE CHATELIER CEMENT TESTING APPARATUS.

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COTTON GINS.

By Wm. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

THE operation of stripping the fibres of cotton from the seeds was doubtless at first performed by hand. This must have been a very slow and tedious process, and no doubt prevented the extensive use of cotton for some considerable period after other fibres had become thoroughly established as articles of common use. A cotton-pod contains a large number of seeds, and each seed is surrounded by innumerable fibres growing from its skin or outer covering. The detachment of the fibres from the seed presents a problem which had to be solved before cotton could be used to any extent for textile purposes.

The earliest gin of which we have any record is the one known as the foot-roller gin. It consists essentially of a slab of stone or wood, and a roller. The cotton from the plant was placed on the slab, Fig. 1, and the roller pressed to and fro by means of the feet of the attendant. This action squeezed the seeds away from the fibres; and by this very crude method cotton was obtained, which could be spun and woven into excellent materials. In the outlying districts of India large quantities of cotton, for local use, are still ginned by this primitive method, the production being from four to six pounds of clean cotton per day from each labourer.

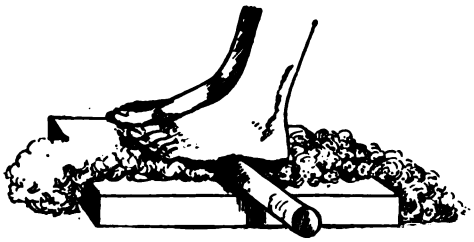

FIG. 1.—FOOT-ROLLER GIN.

The next advance was made by the introduction of the Churka gin. The same principle was used as in the foot-roller gin. Two rollers were supported in a framework, the top small one, of iron, being revolved at a higher speed than the large lower one. The fibres of cotton were carried through between the rollers, and the seeds left behind. Six to ten pounds of clean cotton could be obtained in this way per day. Large numbers of these machines are still used to-day in India and China, by villagers in out-of-the-way districts.

When cotton came to be used on a large scale in other countries than the East, the necessity for large productions to meet the demands gave rise to rapid developments in the cotton gin. Progress came from the side of those who wanted the cotton rather than from the growers; so that gins, as we know them to-day, date from the rise of the cotton industry in England and America.

Among many attempts made, the machine invented by Macarthy has stood the test of time; and at the present moment the greater part of the cotton crop of the world, outside America, is ginned by machines known by his name.

A section of the Macarthy gin is given in Fig. 3. A leather-covered roller, A, revolves as shown. Pressing against the roller is a steel blade B with a knife edge; springs C keep the blade pressed uniformly against the full length of the roller. The seed cotton is fed along the table and into the hopper receptacle. The fibres come into contact with the rough surface of the leather roller, and are rapidly drawn between the steel knife and the roller,

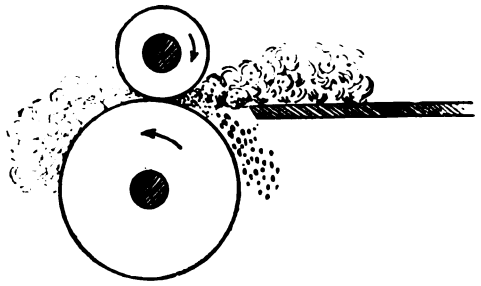

FIG. 2.—CHURKA GIN.

the seeds being left sticking to the edge of the blade. A vertical moving blunt blade of steel F is given an upward and downward motion by the crank R, and the blade F is guided in the right direction by the radial arm G to which it is attached. The action

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of F is to give a very rapid series of taps to the seeds adhering to the doctor knife B, and to so cause them to fall away through the grid T on to the floor. To give some idea of the speeds at which the machine works, it may be mentioned that the leather roller runs at 150 r.p.m., and the beater knife F strikes the seeds at the rate of 800 r.p.m. The production of the machine is over 50 lbs. of clean cotton per hour.

A double form of the Macarthy gin is made, whereby a better balancing of moving parts is obtained, as well as a greatly increased production with smaller speeds. The single machine is always used for good long-stapled cotton such as Egyptian, Sea Island, etc.; whilst the double action gin is chiefly used for Indian woolly seed cottons.

We now come to another type of machine called the saw-gin. The advent of this machine is often said to mark the advent of America's commercial progress. Eli Whitney was the inventor, and his first machine was brought out in 1791. Previous to this year only very small quantities of cotton came to England from America, and that which came was always long-stapled Sea Islands. Uplands cotton was practically unknown before the days of the saw-gin. The short fibres were so difficult to detach from the seeds, that only about a pound of cleaned cotton could be obtained per day from an operator. The Churka gin was used in America before the saw-gin was invented, but only the long-stapled Sea Islands cotton could be cleaned on it.

To illustrate the importance of the saw-gin, it may be remarked that eight bags of cotton arrived in Liverpool in 1784, on board an American vessel, and were seized by the custom house authorities, because it was not credited that the fibre was American cotton. In 1787 one hundred and eight bags were imported, all Sea Islands. Two years after the saw-gin was started the cotton crop of America rose to five million pounds, and has grown enormously since. Uplands cotton in 1791 required two operators to produce two pounds of clean cotton per day; whilst at present two men, in charge of six machines, can produce twenty-four thousand pounds of clean cotton per day.

It is unnecessary to trace the development of the saw-gin since Whitney introduced it. It will be sufficient for the present purpose to give two sketches of it. In the first one, Fig. 4, two rows of saws are shown. Between each pair of saws is passed a plate or bar C, the space between bar and saw being sufficient to allow fibres of cotton, but not seeds, to pass. The seed cotton is thrown into the hopper A, and the saw teeth, revolving at a high speed, carry it round and tear the fibres from the seeds, leaving the latter behind to fall down through the grid E. The brush D sweeps the cleaned cotton from the saw teeth and sends it along in the direction of the arrow at J. The bars C get choked with seeds at times, and when this happens the attendant presses the foot lever and lifts the

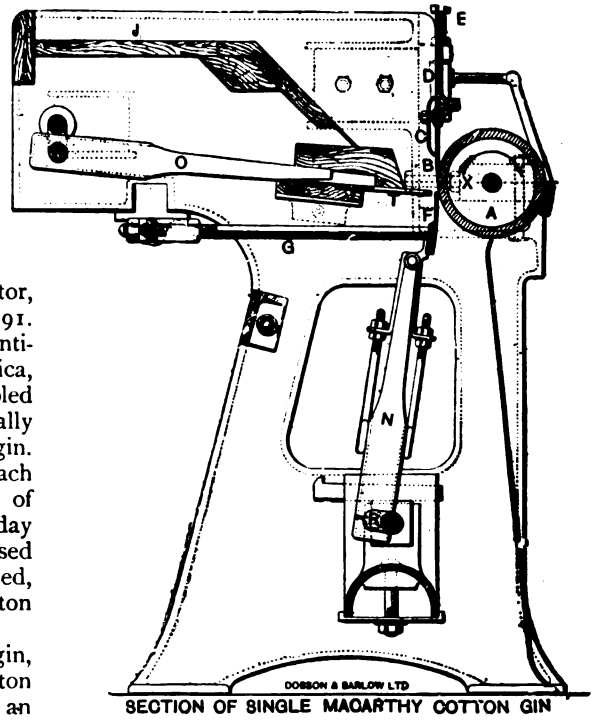

Fig. 3.

bars clear of the saws, and so enables them to be easily cleaned.

A more modern form of saw-gin is illustrated in Fig. 5. The seed cotton has been considerably opened out before being brought to the gin by a machine called a Seed Cotton Opener, which will open as much as a ton of seed cotton per hour. This opened-up seed cotton is dropped on to a travelling lattice A, and is carried forward under a picker roller B, which throws the cotton into a hopper D, and so into what is called the gin breast. Here the cotton comes into contact with the revolving saws F, between which are fixed the bars G. (A side view of the arrangement of the saws and the bars is shown at the right of Fig. 3.) The fibres of

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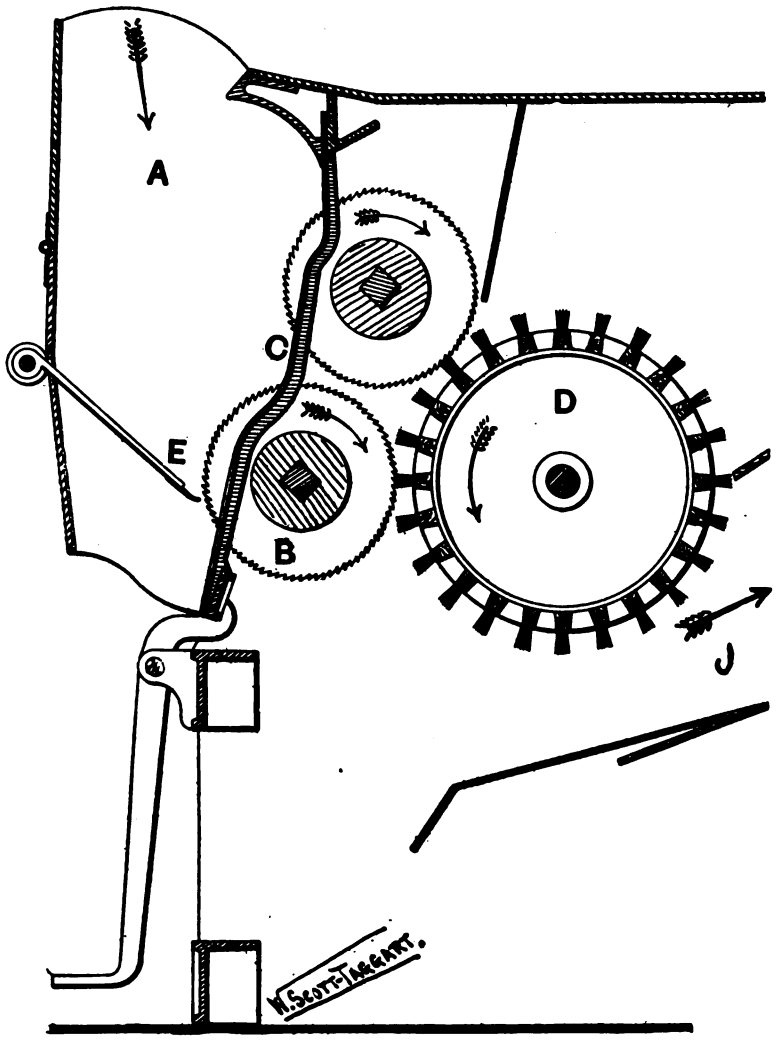

FIG. 4.—THE SAW GIN (OLDER FORM).

cotton are torn from the seeds in passing through the bars, and the cleaned cotton is passed along the passage J, being sometimes assisted by a draught from the drum K. The fibres are carried round between the drum K and a roller L, and from this point are delivered into some receptacle for making into a bale.

Students in England have only the cleaned cotton to deal with; but all practical men in responsible positions realise that the ginning operation is a very important one from several points of view. Badly ginned cotton means very dirty cotton; the skins of the seeds are torn off and broken up, and are difficult to remove in the subsequent processes in the cotton mills, thus entailing additional expense and care. The fibres of cotton are also damaged and weakened, so that the resulting yarn is of an inferior quality. Quality is of vital necessity in the textile trade, so that ginning is a factor to be seriously considered. The saw-gin is clearly a machine for giving a large output at a minimum cost, but it is equally clear that quality is sacrificed to obtain this. The long-stapled cottons are not ginned on this machine; and, strange to say, the greater proportion of the shortest and worst cottons are not cleaned on the saw-gin. These cottons almost invariably pass through the Macarthy gin. This latter gin, however, will produce only 1,000 lbs. of clean cotton per day, whilst a saw-gin will produce 4,000 lbs. per day; so that it is only a

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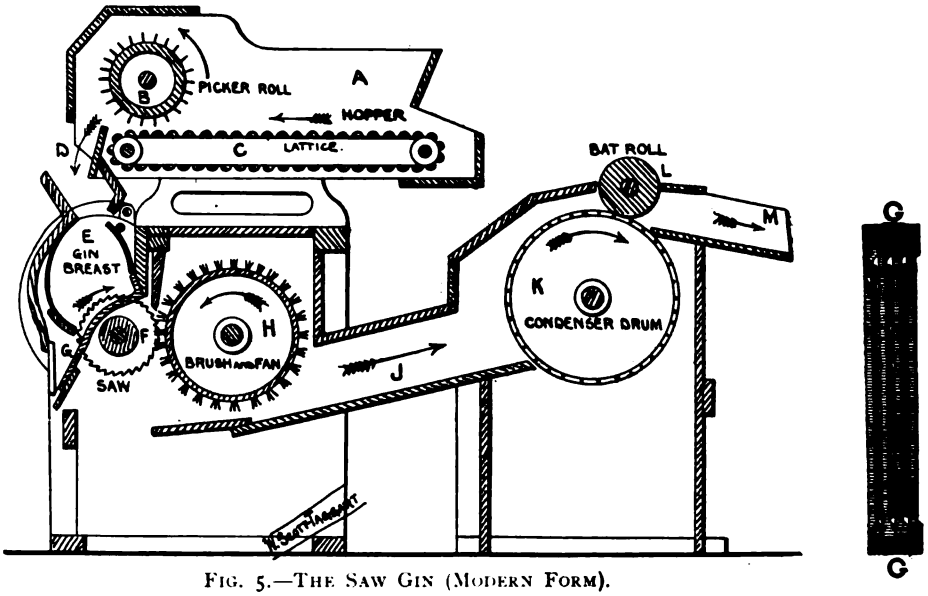

FIG. 5.—THE SAW GIN (MODERN FORM).

question of time for the saw-gin to oust the Macarthy gin from the market. Sea Island cotton, and to a large extent Egyptian cotton, are luxuries; and all operations through which they pass are based on this fact. Present-day students had better prepare themselves for the future by thoroughly grasping this problem of ginning, for there is no doubt that there are distinct signs of competition and labour conditions compelling the adoption of the saw-gins in other than the American cotton-fields. In conclusion, it may be said that the amount of "lint" (as the cleaned cotton is termed) is usually about one-quarter of the seed cotton put in at the gin, so that for every ton of seed cotton gathered, only 600 lbs. reaches the spinning mill.

RECENT GAS AND OIL ENGINE DEVELOPMENTS.

By THOS. HOLGATE, M.I.C.E.

MOST of the engines exhibited at Earl's Court were of the single cylinder horizontal type; they showed that development is proceeding along the lines (*a*) of higher compression of the charge before ignition; (*b*) of employing electric ignition in lieu of tubular; (*c*) more convenient means of starting; (*d*) in large engines, of water cooling for the exhaust valves. These advances in recent years, combined with better governing, have brought about considerable reduction in the cost of gas for working, and increased satisfaction in the uniformity of power generation.

The Simms-Bosch igniter appeared upon the majority of the engines, and it is evident that the replacement of tube ignition which has very largely taken place on the continent has now set in for this country. The embodiment of these several ideas in the "Stockport" engine, made by J. E. H. Andrew & Co., Ltd., may be regarded as almost typical of many of the well-known makers, whose machines it is impossible to describe further. The compression is 100 to 180 lbs. per square inch, according to size of cylinder. Those of 125 B.H.P. and upwards have water-cooled exhaust valves. The starting is done by means of a pump, and the ignition by electricity. The late starting of the latter is effected by hand, on trip gear provided.

The Westinghouse engine was represented by drawings and photographs of the various combinations of vertical cylinders that they

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make up to large powers. The starting is done by compressed air from a cylinder previously charged during the working of the engine. The governing is done by controlling the quantity of gas and air admitted per charge, whilst the ignition by electricity is expected to receive an early development by the adoption of Sir Oliver Lodge's new system.

The smallest engines using gas, within the grounds of Earl's Court, were the Lowne patent atmospheric engines. They are made in five sizes, the largest giving one-half horse-power, and the smallest one-fortieth of a horse-power; they are therefore suitable for light work such as a hot-air engine would usually perform. The power exerted is due to a reduction of pressure caused by cooling the products of combustion of gas or oil, when they come in contact with the walls of the water-jacketed cylinder. The utilisation of vacuum was effected for part of the power in the Otto and Langen or flying piston engine, but in the "Lowne" the whole of the power is obtained from that source at a pressure of five to six pounds per square inch below atmosphere. A No. 2 size, having a cylinder of 2 inches diameter, a fly-wheel of 12 inches diameter, and of 26″ × 17″ × 17″ height, width and depth respectively, and weighing 32 lbs., as made by Messrs. Hardy and Padmore, Ltd., has been tested and found to give, at 480 revolutions per minute, nearly one-tenth of a horse-power; but at 400 revolutions, a better working speed, the horse-power was ·076. The consumption of London gas was 100 cubic feet per B.H.P.

A gas flame burns at the top of the vertical cylinder, and the piston, for about the first half of its stroke, draws the flame and its products into the cylinder through a valve which then closes. By the time the piston has completed its outstroke the products N_2, H_2O, and CO_2 have been cooled sufficiently to create a negative pressure of five to six pounds per square inch, the condensation of the steam conducing to this result. The pressure of the atmosphere above that in the cylinder expels the products, and the valve is again opened and the cycle repeated. It is thus seen that the working parts are few—as befits a domestic motor—that there is no compression or explosion of a charge, and only one light is required, although as a precaution a small bye-pass light is employed in case the larger one were sucked out by the moving piston. The starting is effected by turning round the fly-wheel by hand, after the gas has been lighted or the oil has been burning for five minutes.

The "Gothic" engine, made for gas or oil, is the invention of Mr. Melhuish, and is made by Messrs. Thos. Glover and Co., Limited, in sizes from 2 to 10 B.H.P. The distinctive feature is that an impulse is given at each complete revolution, or two strokes of the piston; and that this is obtained by the exhaustion of the burnt gases by means of an auxiliary or partial vacuum cylinder, in tandem with the working cylinder.

It has been proved that in using certain oil motors, an increased duty per gallon of oil can be effected by the admixture therewith of a small percentage of water, and this mingling is effected in the "Gothic" engine by the auxiliary piston, which first sucks up the oil from a receiver on the outstroke, and then on the instroke delivers waste gases and water vapour through a small tube in required proportion.

The drawing (Fig. 1), will enable the following description to be understood.

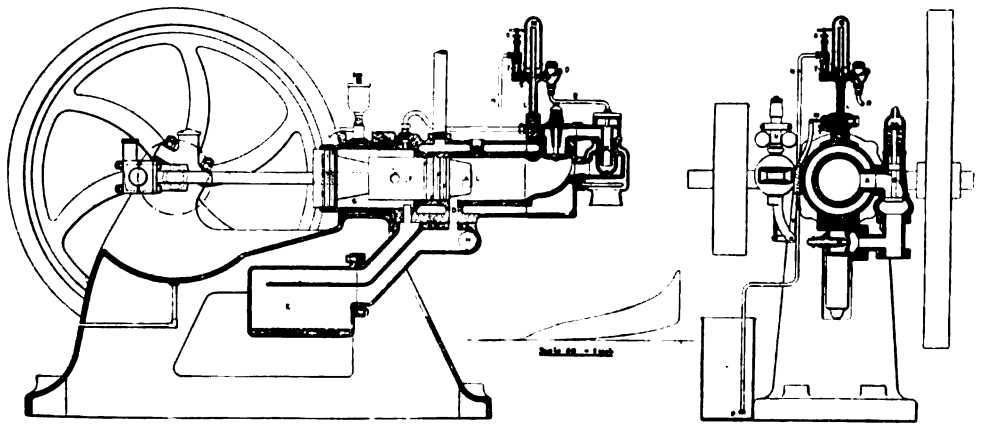

FIG. 1.—THE GOTHIC ENGINE.

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Assuming the piston to be at its complete instroke and a charge compressed—in the case of oil, to 40 lbs., and of gas to 60 lbs. per square inch—this is fired by a hot tube placed horizontally under the carburettor. The flame heating the igniting tube serves also to heat the oil in the carburettor K. The explosion expels the piston on its outward stroke, giving out power as shown by the indicator diagram. When it reaches the part A any pressure remaining passes out through the check valve B (shown in the cross section), thus reducing the pressure in the cylinder C to that of the atmosphere. The continued outward movement then uncovers the exhaust port D. During the operation thus described the front end of the piston creates a partial vacuum in the condenser E. As soon, therefore, as the piston F uncovers the port D, the products of combustion remaining in C are induced into E and the cylinder G. The new charge of air thereupon flows into C (to take the place of the waste gases), entering by the valve shown opening downwards, which is hereinafter explained, is also under the control of the governor. On the return stroke, the products in the condenser E are displaced through the valve H into the exhaust pipe I. The lower part of the condenser is preferably covered to a depth of half an inch with water; and by the rapid expansion and the evaporation of the water therein by the products of combustion, the portion of these entering the cylinder G is comparatively cool. The vacuum created in this cylinder is used to lift the oil from the container J and deliver same in definite quantities to the vaporiser K. This is done through the communication of the partial vacuum along the pipe L to the vessel M. The latter is connected by the pipe N and regulating cock O on one side, the lower end of the pipe N terminating in a non-return valve P. On the other side of the vessel M is a delivery valve Q, and a pipe R leading into the vaporiser K. Now, at every *outstroke* of the piston the partial vacuum lifts a quantity of oil (the amount being determined by the cock O) into the small cavity S of the vessel M, the oil being visible as it feeds through the glass T. On the *return stroke* the pressure exerted by the pump piston drives the oil out through the non-return valve into the vaporiser K. Some of the waste gases, and the steam generated thereby in the condenser are then driven through the pipe L into the vessel M, and are condensed as water; after mixing they are driven with the oil into the vaporiser K. When this mixture enters the working cylinder with its proportion of air the effect of the water is to delay combustion. The governing is effected by the belt-driven centrifugal governor U, connected by a central spindle to the bell crank lever V, attached by a link W to a plunger X, that by its movement to and fro, opens and closes communication between the vessel M and pump cylinder C, thereby shutting out the action of the pump and stopping the supply of oil. Should the governor belt break, or should the governor from any cause stop, the plunger in this instance moves out, and by preventing the flow of oil stops the engine. A stepped catch Y holds the plunger at starting the engine, and when the normal speed is obtained, automatically falls and leaves the governor free to act to cut the oil out at too high a speed. The mode of governing just described is that delineated in Fig. 1; but in a later development it has been found an improvement to control the flow of combustible to the working cylinder by the governor opening and closing the spring valve at the top side of the extremity of that cylinder.

The working cylinder is water jacketed. The auxiliary cylinder acts as guide by means of a second piston fitted with rings, to which the connecting rod is secured internally. These details and the lubrication arrangements are clearly shown in Fig. 1, which, representing an oil engine, is (when the carburettor is removed) also applicable to the gas engine.

Russian petroleum with a specific gravity of about 0·82, or low or high flash oil between 85° to 150°, may be used, requiring half a pint per hour per B.H.P.; whilst 20 to 21 cubic feet of gas, having a calorific power equal to that of Manchester, is similarly required.

The engine is an embodiment of the idea long prevalent that a two-cycle engine would give a more uniform turning moment than the prevailing Beau de Rochas or four-cycle. In the various two-cycle designs that have previously been tried, the second cylinder has been under pressure: this new type is differentiated therefrom by the fact that the compression and explosion are both in the working cylinder, whilst the scavenging is done by the auxiliary cylinder acting under pressure below that of the atmosphere. As a consequence of the action of the last-named cylinder, there is an absence of the side shaft, skew gears, rocking levers, and cams that are usually required to effect the succession of four-cycle operations in one cylinder.

The engine of Messrs. Crossley Brothers, Limited, direct coupled to an electric

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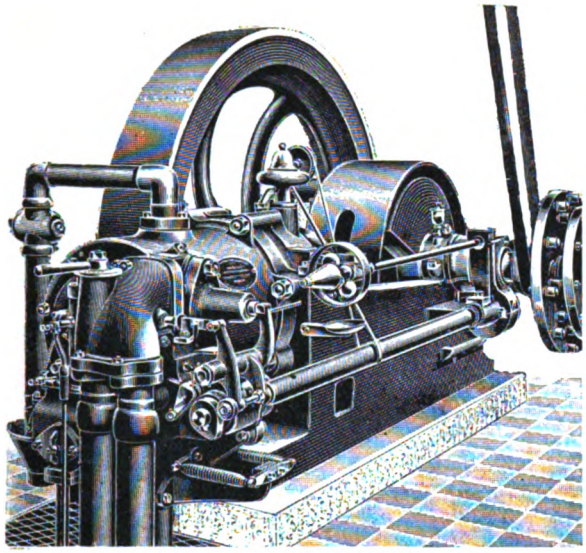

FIG. 2.—CROSSLEY'S ENGINE.

generator made by the Lancashire Dynamo and Motor Company, Limited, runs at 250 revolutions per minute and gives a maximum power of 29½ effective horse. The continuous working load of the engine (S.E. type) is 27½, which, with town's gas of 600 British thermal units net heating value, requires 14½ cubic feet per hour per B.H.P. When gas of 150 British thermal units net heating value is used, the output of power is reduced 20 per cent., *viz.*, to 22 B.H.P., and the consumption raised to 65 cubic feet per B.H.P. Engines of this size work with a compression of 95 lbs. per square inch; but in larger sizes of recent design this is increased to 150 lbs. The heavy fly-wheel necessary to secure sufficient uniformity of speed for the working of electric glow lamps is fitted on a balanced crank shaft supported on an out-end bearing, and this crank shaft is coupled to the dynamo by a flexible coupling. In Fig. 2 this coupling, known by the name of Raffard, is shown. The mode of joining the two discs is by projecting pegs, upon which flexible material, *viz.*, cotton rope, is wound. After the pegs are thus interlaced with the rope, the latter is spliced to make it endless.

Continuous lubrication is provided for crank bearing, and the oil may be collected and re-used for less important bearings if desired. A simple appliance for the collection of oil and prevention of loss by splashing consists of a strip of spring steel, placed in contact with the gun-metal, where the crank shaft is thickened up for passing through the fly-wheel. The horizontally-placed governor shown in Fig. 2 is driven by gearing direct from the crank shaft, and not from the half-speed valve operating shaft. By this mode of driving, the variations of speed are reduced from 2¼ to 1¼ per cent., as between full load and no load. In larger engines this improved governor, acting on a hit-and-miss arrangement, is supplemented by an automatic cut-out gear which proportions the charge of air and gas at the higher loads, but employs the "hit-and-miss" for the lower ones. The heavy fly-wheel keeps the variation of speed at any part of a given revolution (known as the "cyclical variation") at 1¼ per cent., or a total variation of 2½ per cent. Where this is required to be reduced, as in running alternators in parallel, the addition of a second fly-wheel accomplishes it.

The ignition may be either with duplicate hot porcelain tube, when town's gas is used, or by electric spark when fuel gas is used. In the latter case, a Simms-Bosch electro-magneto machine A, having an oscillating sleeve B, is employed (see Fig. 3). The magneto consists of three permanent horse-shoe magnets, an armature having a primary and secondary winding for the high tension type, and one winding for the low tension, and a shield or sleeve. The magnets and pole pieces are secured to a gun-metal base plate, which is supported from the engine by the bracket R.* As the low tension type has alone been used on stationary engines, we describe that only. A single wire connects the armature with the sparking box N, with contact breaker K and L to form the spark; this box N is fixed on the engine cylinder, and is fitted with a sight hole X. At this box the sparking may be examined when gas is absent, by pulling over and liberating lever T. The engine side shaft has a special cam E and trip gear T, to give a quick motion to the magneto oscillating sleeve B; and it is also provided with a late sparking cam E, for starting the engine without fear of its running the wrong way, which it would do if the ignition took place before the dead centre of the crank had been passed. The gear acts as follows: The trip lever T is pulled over by a trip

* For further description of the principal details of this machine, see TECHNICS, Vol. I., p.p. 351–2.

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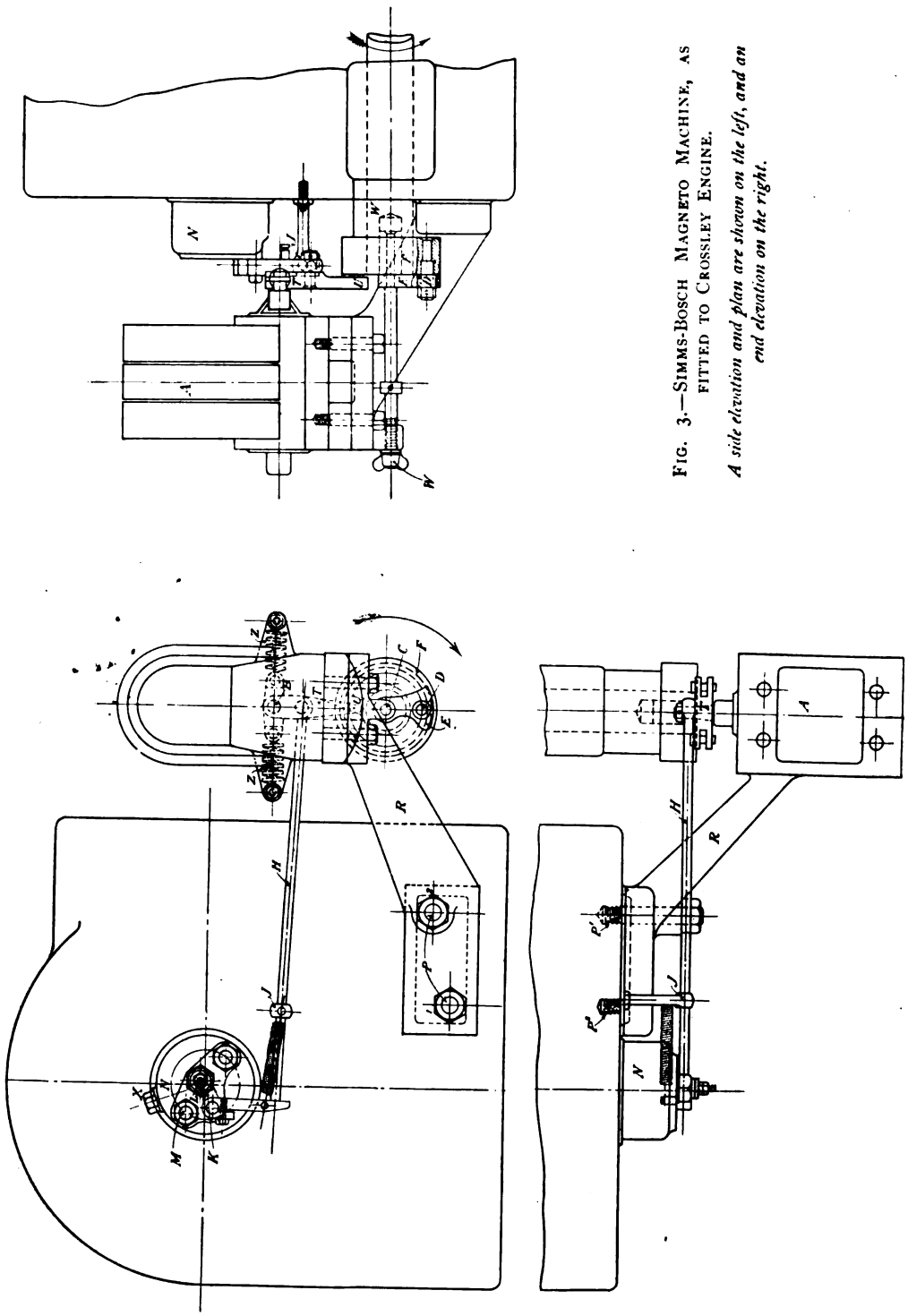

FIG. 3.—SIMMS-BOSCH MAGNETO MACHINE, AS FITTED TO CROSSLEY ENGINE.

A side elevation and plan are shown on the left, and an end elevation on the right.

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roller D, fixed on the side shaft cam F. At the correct moment the trip lever T is released; then, by means of the two springs ZZ, the lever flies back to its normal position at U, making the electric current, the trip lever T at the same time breaking contact in sparking box N by means of pusher rod H, and forming electric spark in box N, when the charge is ignited. The engine having started running, the late starting cam E is disengaged by a thumb-screw W under the magneto A (Fig. 3). The current generated by the magneto is conveyed by the single wire to the ignition plug, consisting of an insulated pin and a moving lever, which are separated mechanically by the engine, so as to cause the spark to pass, producing the ignition at the proper time. The sparking points K and L adjust themselves to any wear, and they can be readily freed from any water or oil that may be deposited on them, whilst the whole gear can be removed and replaced in a few minutes. As the magneto will give a spark at the slowest speed of rotation of the engine, no difficulty occurs in firing the combustible at the time of starting.

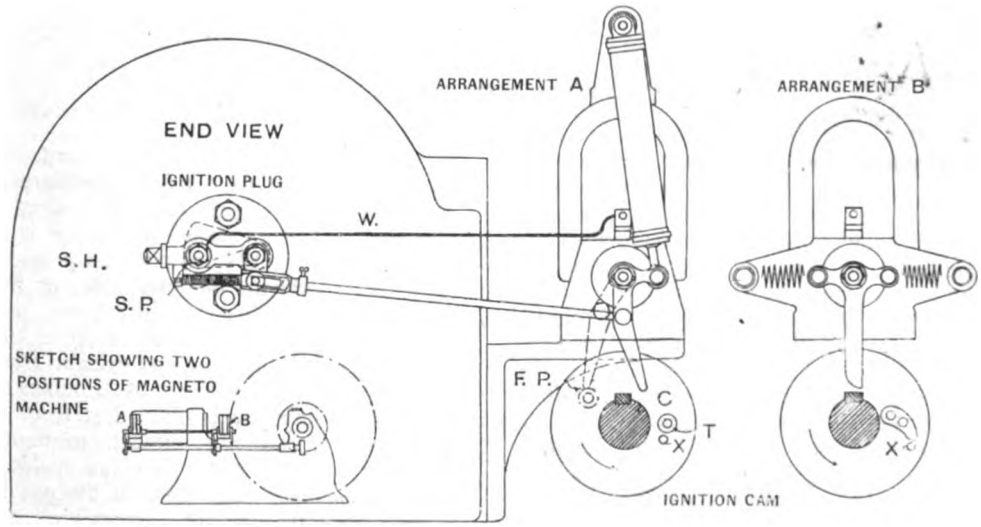

FIG. 4.—DIAGRAMMATIC REPRESENTATION OF TWO TYPES OF SIMMS-BOSCH MAGNETO; ALSO SHOWING TWO ALTERNATIVE POSITIONS FOR MAGNETO.

W, *connecting wire.* F.P., *firing plug.* S.P., *sparking plug.* S.H., *sight hole.* C, *cam.* T, *trip roller.* A *and* B, *alternative positions for magneto. To retard spark, place plug in aperture* X.

A method of retarding ignition at the time of starting the engine is shown in Fig. 4, where two alternative types of, and positions for, the Simms-Bosch magneto are given.

In the air supply tube is fitted a wing valve, actuated by a worm and wheel, which in turn are operated by a small hand wheel. This enables the volume of air to be approximately adjusted to the calorific power of the gas being used.

The Simms Manufacturing Company, Limited, exhibited petrol motors of the single, twin, and four cylinder types, each capable of being operated by gas. An essential part of these motors is the magneto ignition, either by low tension already referred to for stationary engines, or of the high tension or arc light type primarily designed to take the place of accumulators and coils, and more especially of the same as applied to existing multi-cylinder motors on road cars. When the low tension is used for high-speed motors, the rotary armature and rotary sleeve are employed, the "make and break" being effected like that for the stationary engines, and shown in Fig. 11, page 351, Vol. I., TECHNICS.

A $3\frac{1}{2}$ B.H.P. single cylinder cycle-motor has a bore and stroke each of 82 mm., and, as in the larger sizes, the inlet valve is mechanically operated. A float-feed carburettor is fitted, having an automatic mixture regulator, ensuring a constant proportion of petrol vapour and air at all speeds. It is fitted with the high-tension ignition, and the advance sparking gear is contained inside and forms a part of the magneto machine. It is provided with a safety sparking gap enclosed from atmosphere. The range of speed is from 300 to 3,000 revolutions per minute. The height, length, and width over all are $20\frac{1}{4}$, $11\frac{1}{4}$, and

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6¼ inches respectively, and the weight, including the ignition and carburettor, is 65 lbs. A four-cylinder water-cooled motor, giving 20 B.H.P. at 1,200 revolutions, in running order, weighs 370 lbs., of which 68 lbs. is in the fly-wheel. The height from top of compression cock to bottom of crank chamber is 22 inches, the width over frame attachments 16½ inches, and length from end of crank shaft to back of fly-wheel 35 inches. The machine works at a compression of 70 lbs. per square inch, and the diameter and stroke of pistons are 95 mm. and 110 mm. respectively. The weight per B.H.P., *viz.*, 18½ lbs., is very small, and the advent of six-cylinder motors promises still further reduction, due to the absence of a fly-wheel made possible by the absolute uniformity of turning moment on the crank shaft.

Each gas-engine maker applies the magneto to his mechanism in a slightly different manner, and the principle of the same is embodied in Fig. 4, where the standard or suggested methods are delineated. This low tension magneto is made in three classes: (*a*) with oscillating sleeve, (*b*) with rotary armature, and (*c*) with rotary sleeve. In these three classes are modifications to suit (*a*) single, or (*b*) multiple cylinder motors, or (*c*) high-speed motors, and (*d*) slow-speed motors. The rotary sleeve type recently introduced includes the advantages of the oscillating sleeve and rotating armature; that is to say, it has a rotating movement of the sleeve and a fixed armature arranged in such a manner that the current does not pass through the bearings. The armature is adjustable, and allows of a variation of 120° in the sparking position. With this machine four sparks are obtained every revolution, thus allowing it to be operated from the half-speed shaft of the engine. The oscillating sleeve is, however, more suitable for one or two-cylinder motor-car engines, where only a limited space is available for the magneto drive, the oscillating machine being very easily connected up.

ACETYLENE PURIFICATION.

P. GRIL proposes, in his French patent 334111 of 1903, to extract from crude acetylene made from calcium carbide, the organic compounds of sulphur, the basic compounds formed by polymerisation, and the phosphine which it usually contains. For this purpose ten parts of chromic acid are dissolved in thirty parts of nitric acid, and the solution is absorbed in 100 parts of kieselguhr. Messrs. L. M. Bullier and L. Maquenne, who have investigated the origin of the impurities usually present in crude acetylene made from calcium carbide, state that the compounds of phosphorus come from the calcium phosphide in the latter material. They find that this phosphide, and the analogous calcium sulphide, only occur in carbide when it is made by the usual "basic" process —*i.e.*, when the charge fed into the electric furnace contains lime in excess. If the carbide were prepared with carbon in excess it would not be so contaminated. The white haze which is produced when C_2H_2 containing PH_3 (phospine) is burnt in a closed room, consists of ammonium phosphate. Ammonia is of itself an objectionable gas, and if it enters into a purifier containing material intended to extract phosphorus, it reacts with that material and lowers its efficiency. The source of the sulphur is not yet traced. The SH_2 was formerly said to come from calcium monosulphide, or from aluminium sulphide; but it appears more likely that it is formed when a triple compound of carbon, sulphur, and calcium comes in contact with water. A troublesome mechanical impurity is lime dust from the gas generator, which is difficult to remove even by a water washer, and is visible in the luminous acetylene flame if the gas has been passed through tubes containing wool moistened with HCl or H_2SO_4. The lime dust deposits at the burner orifices and gradually decreases their effective diameter.

Luigi Mascarelli has examined the "explosive compound" formed, amongst other substances, on slowly passing acetylene through nitric acid of specific gravity 1·52, and finds it to have the composition $C_4H_2O_7N_6$. When heated with caustic potash this substance gives off ammonia, and on being heated with light petroleum it also suffers decomposition.

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THE DETERMINATION OF CHROMIUM IN HIGH-SPEED STEELS AND ALLOYS.

By FRED IBBOTSON, B.Sc.

THE simplest and most rapid method of estimating chromium consists in its conversion to a salt of chromic acid, followed by titration with a ferrous iron solution and potassium permanganate or bichromate. Oxidation in a solution can be accomplished in many ways, but no oxidising agent acts so quickly and effectively as the potassium or ammonium salt of persulphuric acid.

The present retail price of these compounds —about eight shillings a pound in the case of the ammonium salt, and, on account of its smaller solubility in water, only about five in the case of the potassium salt—is by no means prohibitive, and they are now being used extensively for oxidising and other purposes. Amongst others, the conversion of the manganese in a steel into permanganate is worthy of mention.

As practised by the author, the oxidation and subsequent determination of chromium in a steel can be conducted in the flask into which the drillings are first weighed, without resorting to a single filtration, and duplicate assays can easily be made in less than an hour.

Process for Steels.—Half a gram of the drillings are placed in a small flask and covered with 10 cc. of dilute sulphuric acid (1 acid to 4 water). Heat is applied to assist the breaking up of the steel, and when decomposition is complete, or nearly so, a few drops of strong nitric acid are added to oxidise the iron, and the nitrous fumes thus generated are then expelled by boiling. About 100 cc. of water are next added, together with 20 cc. of nitric acid (specific gravity 1·20), and 20 cc. of a solution of silver nitrate, made by dissolving 2 grams of the crystals in a litre of distilled water. Two or three grams of solid ammonium persulphate are then added, and, after washing down any particles of the salt adhering to the neck or sides of the flask, the whole mixture is heated.

Oxidation of the chromium (and the manganese) soon sets in, and the green colour of the solution is replaced by the characteristic yellow of chromates. This may be modified or masked completely by the purple tint of the permanganate formed from steels containing manganese. High-speed steels, however, contain only a trace of this element, and many none at all, so that there is no appreciable interference from this source.

As the temperature rises, a brisk evolution of oxygen gas sets in, due to the decomposition of the excess of ammonium persulphate. This decomposition is brought about catalytically by the silver nitrate added. The expulsion of oxygen should be assisted by frequent shaking, so that it has practically ceased when boiling point is reached. The solution may then be boiled not longer than half a minute, after which it is cooled off rapidly under the water tap.

Without filtering off the tungstic oxide, which has separated in considerable quantity, the solution is largely diluted, and an excess of a ferrous sulphate solution, of approximately one-twentieth normal strength, added to reduce the chromic acid. The excess of ferrous iron is then titrated with potassium permanganate of the same strength.

$$1 \text{ cc. } \frac{N}{20} \text{ potassium permanganate} = 0{\cdot}000868 \text{ grams chromium.}$$

The end point of the reaction is not materially obscured by the precipitated tungstic oxide.

Process for Alloys.—The procedure just described for steels is applicable in its entirety to rich chromiferous ferrotungstens, once these refractory alloys have been suitably opened out. An easy method of doing this is described by the author in TECHNICS, Vol. II., p. 461, under the determination of tungsten. For present purposes, one quarter of a gram of the crushed specimen is treated with a few cubic centimeters of hydrofluoric acid, and strong nitric acid is then added in drops until no further action takes place. The whole mixture is then evaporated, after adding 2 cc. of strong sulphuric acid, to the complete expulsion of the more volatile acids as indicated by the appearance of sulphur trioxide fumes. The residue is then washed from the platinum dish or crucible into the flask and the assay carried forward.

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REVIEWS.

Elements of the Mathematical Theory of Electricity and Magnetism. By J. J. Thomson, M.A., D.Sc., LL.D., F.R.S., etc., Cavendish Professor of Experimental Physics in the University of Cambridge. Third Edition. pp. viii. + 554, with 134 illustrations. (London: C. J. Clay & Sons, Cambridge University Press Warehouse, Ave Maria Lane. 1904.) Price 10*s*.

The student who has obtained an accurate elementary knowledge of the science of electricity and magnetism from the experimental standpoint, and wishes to extend his studies into the more abstruse, but no less valuable mathematical theory of the subject, cannot do better than use this book. Works like Maxwell's classical treatise, and several other books dealing with the mathematical theory of electricity, present almost insuperable difficulties to the reader who has not mastered the whole range of modern mathematics; but Professor Thomson has reduced the subject to its simplest elements, and the reader who follows the argument, as set forth in the book before us, will obtain a thoroughly trustworthy knowledge, which will prove invaluable to him in his subsequent studies. Only simple mathematics are used; the reader requires a good working knowledge of the differential calculus, but this knowledge is no more than is commonly possessed by advanced students. It is not at all necessary to make use of advanced analysis to establish the existence of some of the most important electro-magnetic phenomena. There are always some cases which will yield to very simple mathematical treatment, and yet establish and illustrate the physical phenomena as well as the solution, by the most elaborate analysis, of the most general cases which could be selected. The value of Professor Thomson's book depends largely on the skill with which these cases admitting of simple solution have been chosen.

Even students whose mathematical equipment would enable them to understand the elaborate analysis used in more advanced treatises, will find it advantageous to read the book now under consideration. The absence of analytical difficulties permits the attention of the reader to be directed to the physical aspect of the subject, so that he acquires a more vivid idea and a more manageable grasp of the subject than he would be likely to attain if he merely regarded electrical phenomena through a cloud of analytical symbols.

The most important alteration made in the third edition is a new chapter on the properties of moving electrified bodies; many of these properties may be deduced in a very simple manner; and the important part played by moving charges in modern physical theories amply justifies a discussion of their properties.

The Theory of Determinants and their Applications. By Robert Forsyth Scott, M.A. Second Edition, revised by G. B. Mathews, M.A., F.R.S. pp. xii. + 288. (London: C. J. Clay & Sons. 1904.) Price 9*s*. net.

This book is acknowledged as the standard work on Determinants. Having stated this, we need only refer to the changes introduced in the present edition. The character of the book has not been altered, nor has the size of the book been increased. Instead of the bibliography included in the earlier edition, an account of the earlier theory of the subject has been given. A new introductory chapter has been written, which will prove useful to beginners who might otherwise become discouraged by the difficulties of the subject. The abbreviated notation, employed in some chapters, has not been used in those which are more elementary. The mathematical student may find in this volume practically everything connected with the theory and application of determinants which he is likely to require in his studies.

Electrical Engineering for Electric Light Artisans and Students. By W. Slingo and A. Brooker. New Edition. pp. viii. + 814, with 383 illustrations in the text. (London: Longmans, Green & Co., 1903.) Price 12*s*.

The numerous editions which this book has run through since its first publication in 1890 bear sufficient testimony to its sustained popularity. It was written to assist students to prepare for the ordinary grade examination of the City and Guilds of London Institute; and so far as this can be done without devoting a great amount of attention to calculations, it fulfils its object. The writing is clear; the authors have wisely resisted the temptation to attempt a description of every electrical appliance now in use, and have instead confined their attention to only the most important machines and instruments in common use. It is perhaps impossible for the electrical engineering student to obtain a single book which will give him all the information he requires for progress in his calling. Problems so many and so various require his attention, that limits of space alone would prevent adequate treatment of them all in a single book; but most students who have used "Slingo and Brooker" in the past will testify to the advantages they have derived thereby, and it is probable that many of the students now commencing their studies will acknowledge the same indebtedness in the future.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the* 10*th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

WEAVING.—It is considered most essential for the designer of dobby figured fabrics to have a practical acquaintance with the preparatory processes, and also with the mechanism of weaving; more particularly regarding all shedding and checking motions. Why is this knowledge desirable, and of what value would it be if he had to change from dobby stripe shirtings to:

(*a*) Extra warp figure effects suitable for blouses?

(*b*) Large dobby check designs suitable for washing dress materials?

(*c*) To leno gauze stripes suitable for dress materials?—(*City and Guilds of London Institute, Cotton Weaving, Honours Grade—General Section, Question* 5.)

The manufacture of textile fabrics comprises a series of operations and processes, each of which forms an integral part of a complete scheme culminating in the finished article. Although these operations may be conducted separately, yet they are so co-related that each has a more or less direct bearing upon the others. They may not, therefore, with impunity, be performed as abstract operations.

The preliminary stages of manufacturing, by which warp and weft are prepared for the loom, are known as "preparatory processes," of which a designer for coloured fabrics should have some technical knowledge, to guide him to what extent he may safely go in respect of the size and character of warp patterns that may be produced by the plant at his disposal, and how to conform to the restrictions imposed by such plant. Or, if he has the choice of additional plant, his knowledge will enable him to choose such as will best and most economically meet his special requirements. For the fabrics enumerated at (*a*) he would adopt some simple and inexpensive means of preparing warps containing comparatively few warp-ends, and of winding them upon small warp-beams to furnish the extra figuring threads.

But it is, perhaps, of greater importance that a designer should be intimately conversant with power-looms and their numerous accessories, especially as regards shedding appliances, "checking" or box motions, and picking (including "pick-and-pick") motions. He would then know what would best meet specific requirements. If he were changing from dobby stripe shirtings to blouse fabrics to be figured with extra warp-ends, he should know not only the limitations imposed in respect of warping, but also if the loom at his disposal is adapted to receive the requisite number of healds, as well as an extra warp-beam. He should also know if the dobby has a sufficiently large heald capacity to enable fairly effective figures to be produced by it; and he would select a dobby of lighter construction than one required for shirtings and other heavier textures.

If he were cognisant of the irregularity of tone common to hank-dyed yarn, or of the evil effects upon yarn in respect of glazing, caused by pirn-winding,* he would know that it would be unwise to employ a single-box loom to weave coloured weft, unless the bobbins of weft were previously "boxed" and especially selected for their uniformity of tone and comparative freedom from glaze; otherwise, "shaded" cloth would result from the juxtaposition of weft of various depths of tone. If such precaution were not exercised to secure the least faulty weft, and bobbins were used indiscriminately, it would be advisable to employ a check-loom and weave with two shuttles containing similar weft, when two picks may be inserted by each shuttle alternately, and thereby neutralize any irregularity of tone that may exist—not forgetting that the use of a check-loom would involve a higher rate of pay to a weaver.

If a designer had to prepare designs for fabrics enumerated at (*b*), he would require the use of a check-loom, and should know something of its capabilities, to enable him to obtain the best results, and not waste his time in preparing designs which he may subsequently discover are beyond its possibilities. He must know the greatest number of shuttles it is capable of weaving with at one time, and whether it may skip only one shuttle-box, or more than one at will. He will also endeavour to dispose the different colours of weft in the fabric so that most of the shuttle-boxes will be below the shuttle race-board for the greater period of time, and thereby keep the centre of gravity of the slay at a point nearer the rocking-shaft; and also so that shuttles may be brought into position for picking with the least movement of shuttle-boxes. A change from one box to any other is made in the same measure of time, irrespective of their relative positions; therefore, the speed at which boxes move, when changing,

* See "Special Devices used in Weaving"—Parts III. and IV. in the January and current issues of TECHNICS.

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will be proportionate to the space through which they travel; consequently, more wear and tear of parts will result from longer than from shorter movements of boxes. For these reasons, a skip of more than one box—as from No. 1 to No. 3, or No. 2 to No. 4, and *vice versâ*—should be avoided, as far as practicable, by placing the various colours or counts of weft in such relative positions as will best meet that requirement. If the various motions of a loom, especially those governing shedding, picking, and shuttle-boxes, are so controlled that they always act in perfect unison, it will be safe to weave more complex check patterns than if those motions were governed in a negative manner. In the latter case they would be liable to get out of unison, and thereby spoil the pattern, besides proving a serious tax upon a weaver.

If a change were to be made from shirtings to "net leno" fabrics suitable for dress materials, as at (*c*), a designer would require to have a good knowledge of leno weaving, and of the numerous accessories of a leno loom. He would then know that an ordinary double-acting open-shed dobby would be unsuitable, and that he would require one furnished with a "leno" or "shaker" motion, whose function is to raise front standard and doup healds, in a "top doup" harness (or back standard healds in a "bottom doup" harness), with the object of bringing doup and standard warp-ends parallel, to facilitate their crossing with each other. If, however, an ordinary open-shed dobby *were* employed for leno weaving, the loom would require to be furnished with means for "shaking" or "vibrating." The loom should also be capable of receiving such number of additional warp-beams (to contain "net" warp-ends) as corresponds with the number of doup healds employed, as well as a similar number of "easing bars" to "slacken" doup warp-ends during the formation of a "cross" shed.

In short, if a designer is practically acquainted with the routine of mill work in general, and with power-looms in particular, he will be in a position to introduce original ideas and novelties into his designs, and to suggest the necessary modifications that would be required to carry his ideas into practical effect; but if he lacks that acquaintance with technical matters, he will be unable to overcome any difficulties that may arise, and his work will necessarily be commonplace, devoid of interest, and characterless.

PHOTO. — How are the following crystoleum mediums prepared:—

1. Adhesive.
2. Clearine.
3. Preservative?

1. The *adhesive* medium is used to attach the photo to the glass, and should be of such a nature that it will not interfere with the mediums used in the later stages of the painting.

A clear solution of gum arabic is found to satisfy all these conditions; the ordinary gum arabic has a yellowish tint, but this may be got rid of by exposing to air and sunlight at the temperature of boiling water.

2. The *clearine* medium. This medium produces transparency of the photograph. It is prepared by dissolving pure Canada balsam in either benzene or chloroform (the former is the cheaper). This is applied to the photograph when it has been stuck on the glass, and is left until all the "spirit" has evaporated.

3. The *preservative* medium. This medium is applied to prevent fading or gradual appearance of white blotches which occur when the paint actually comes into contact with the photograph. It is prepared from ordinary gum copal in the following way:—The gum, which is in small lumps, is heated to about 400° F., volatile oils being driven off. The residue is taken and mixed with "boiled" linseed oil until dissolved (this takes from two to three hours), when the solution is so viscous that it can be "pulled" just like transparent elastic; the addition of linseed oil is concluded. For use in crystoleum painting the gum copal varnish, as prepared above, is usually thinned down with turpentine, or with a mixture of boiled linseed oil and turpentine.

MANHATTAN BAROMETER.—Upon what principle does the action of the Manhattan barometer depend?

The Manhattan "barometer" consists of a glass tube about six inches long, sealed at both ends, and nearly full of a colourless liquid containing feathery-looking white crystals. In fine weather these crystals sink right to the bottom, but on the approach of rain the crystals gradually rise.

This query is reminiscent of old logical fallacies of assumption, of which one example was the advocate's question—when did you leave off beating your mother?

The instrument in question is not a barometer, and that it may foretell rain in some cases is due to a preceding fall of temperature, and not to any pressure effect.

Thomas Russel, a great American authority on weather prognostication and meteorology, describes the instrument thus:—*The Camphor Thermoscope*, consists of a sealed glass tube containing camphor gum dissolved in alcohol. It is sometimes used to indicate changes of temperature. When the temperature is high the camphor is all dissolved, and when the temperature falls the camphor crystallises out, forming a flocculent, feathery-looking whitish mass. Thermoscopes of this kind are sometimes sold mounted on the same board with a mercurial thermometer, and are erroneously supposed by some to indicate changing pressure or electrical condition of the atmosphere.

HYGROMETRY. — Some air which is not quite saturated with moisture is passed into a dry bottle and the bottle is securely corked. If the temperature of the bottle is now raised, what alteration will be caused in: (1) the dew-point; and, (2) the degree of humidity of the enclosed air?

1. Raising the temperature of the air has nothing whatever to do with changing the dew-

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point, but the fact that the water-vapour and air have a constant volume does cause an alteration. It is simply the case of the alteration of dew-point from constant pressure to constant volume.

Suppose the bottle cooled, then the mass of vapour per unit volume remains unchanged, but by the time we arrive at the temperature at which water would begin to be deposited, had the volume been allowed to diminish, the mass per unit volume will not be enough to quite saturate the air, so that we must cool the bottle a little more ; that is, the constant volume dew-point is a little below the constant pressure dew-point.

2. Defining the *absolute humidity* as the mass of vapour actually present in a unit volume of moist air, we see that this quantity is independent of the temperature of the bottle, unless cooled below the dew-point.

Relative humidity is defined as the ratio of the actual mass of vapour in unit volume of moist air to the mass of vapour required to saturate the unit volume at the given temperature. As the mass required to saturate unit volume increases with the difference between the actual temperature and that of the dew-point, and as keeping the air at constant volume lowers the dew-point, we see that the relative humidity is less under the condition of constant volume.

FIG. 1.—(DUDDELL OSCILLOGRAPH.)

DUDDELL'S OSCILLOGRAPH.—Describe carefully Duddell's Oscillograph. What is its use ?

The wave-form of an alternating current is a very important factor in the working and efficiency of some forms of alternating current appliances, and much attention has been paid to the determination of the shape of the alternating current wave, and to the effects due to different wave forms. In an instrument designed to delineate the wave form of an alternating current or P.D., the elimination of errors due to the inertia of the moving parts presents difficulties of no mean order, since the frequency of the alternating current, even of the order of fifty cycles per second, obviously makes it difficult to construct an instrument with moving parts which must pulsate in perfect synchronism with the current, so as to give a measure of the instantaneous values of the alternating quantity required, and so enable a continuous record of the wave and wave-form to be obtained.

The best known instrument for obtaining delineations of periodic quantities is the oscillograph, which was first introduced by Professor Blondel. Mr. Duddell has applied the same principle of action in the Duddell oscillograph, and has been very successful in evolving a really beautiful and useful instrument of research, a good idea of which may be gathered from Fig. 1. The oscillograph is a highly specialised and modified form of the moving coil or D'Arsonval galvanometer combined with a rotating or vibrating mirror, and consists essentially of two parallel strips of phosphor-bronze *s s* (Fig. 2) formed by bending the strip back on itself over the pulley P, which is attached to a light spring balance introduced to stretch the strips located in the narrow gap between the poles N S of a powerful magnet. At the bottom ends the strips are clamped on a block K, while at the top they are held in position by the bridge piece L.

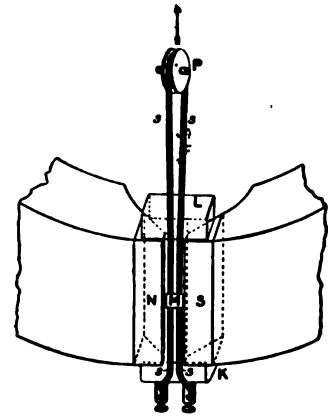

FIG. 2.—(DUDDELL OSCILLOGRAPH.)

By altering the tension on the spring stretching the phosphor-bronze loop, the periodicity of the instrument can be varied at will. Each strip or leg of the loop passes through a separate gap (not shown in Fig. 2) in the magnetic circuit. The clearance between the sides of the gaps and the moving strip is but 0·038 mm. ; and these gaps are filled with a viscous oil, over which is placed a small lens, which is held in position entirely by the surface tension of the oil, and

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serves in its turn to keep the oil in place. The object of the oil is to damp the movements of the strips. A small mirror M (Fig. 2) is attached to the loop as shown. The phosphor-bronze strip forms part of the circuit, so that the alternating current passes up one strip and down the other; and from the principles of electro-dynamics (*i.e.*, a conductor carrying a current and situated in a magnetic field, so that the current is normal to the direction of the lines of force, experiences a force tending to move it in a direction perpendicular to the directions of both the current and the magnetic field) it is obvious that the movements of the two strips will be in opposite directions; as one advances and the other recedes, the mirror is turned about a vertical axis. In the high-frequency instrument the natural period of vibration of the loop is $\frac{1}{10000}$th of a second, and the clearance being extremely small, the damping effect of the oil is so great, that the instrument can be relied upon to give accurate results, even when the periodicity of the current to be tested is over 300 periods per second. Small fuses below the loops protect these from injury in case of accidental excessive current. The fuses consist of very fine wires enclosed in glass tubes, which are held in position by spring clamps.

The beam of light reflected from the mirror M is received on a screen or photographic plate, the instantaneous value of the current being proportional to the linear displacement of the spot of light so formed: with alternating currents the spot of light oscillates to and fro as the current varies and would trace a straight line. If, however, a second mirror be interposed in the path of the beam of light and be caused to vibrate or rotate so as to impart to the beam of light a uniform motion proportional to time in a plane at right angles to the plane of vibration of the beam due to the current, the spot of light will trace out on a stationary screen or plate the time curve of the variation of the P.D. or current. In the case of periodic quantities, as with alternating currents say, the second mirror can be synchronised and the spot of light caused to trace out the wave-form over and over again. In practice the synchronous vibration of the second mirror is obtained by means of a specially designed alternate current motor, fed from the same supply mains.

There are two types of the Duddell oscillograph, known as the single and double types of oscillograph, according as one or two pairs of strips are used, but in both types there is only one magnetic field. With the double oscillograph (see Fig. 1) observations or records can be made of any two currents or P.Ds., or of a current and a P.D., absolutely simultaneously, and it has in addition a fixed mirror to give the datum or zero line. The magnetic field is produced by an electro-magnet (excited by continuous current) wound in twelve sections (as shown in Fig. 1), connected in series in two sets of six, the ends being connected to terminals. With the two sets in series the exciting current may be taken from a 200-volt direct current circuit, and if in parallel from a 100-volt circuit.

Duddell's oscillograph possesses the following characteristics:—

1. It has an extremely small periodic time when undamped, *i.e.*, $\frac{1}{8000}$ to $\frac{1}{10000}$ of a second in the high frequency pattern.
2. It is perfectly dead beat.
3. Its self-induction and capacity are practically nil, and it is free from hysteresis errors.
4. Its deflection at any moment is accurately proportional to the instantaneous value of the current up to a frequency of 300 cycles per second.
5. Its resistance is small, from 5 to 10 ohms.
6. Two or more wave forms may be obtained simultaneously.
7. The wave-form may be recorded as well as projected.

A moment's consideration is sufficient to convince one that the ordinary galvanometer with a moving magnetic needle cannot afford means of measuring periodic quantities, since it does not comply with the following essential conditions for projecting, recording and analysing rapidly pulsating phenomena of a periodic character instantaneously. Such an instrument must have—

1. A natural period of oscillation or vibration much shorter than that of the periodic phenomenon which is to be recorded.
2. A small moment of inertia.
3. A degree of damping as nearly as possible critical.

In fact, the moment of inertia of the moving part must be such as to have an entirely negligible influence upon the oscillations it performs under the action of an alternating current; these are the conditions which have been realised to a high degree in the Duddell oscillograph.

RAIN-GAUGE. — Describe, with the help of sketches, a standard form of rain-gauge. Explain carefully the effect on the record of (*a*), the height of the gauge above the ground; (*b*), the presence of buildings or trees close to the gauge.

How would you determine, in any given place, the relation between evaporation and rainfall? (*B.Sc.*, 1904, *Hydraulics*).

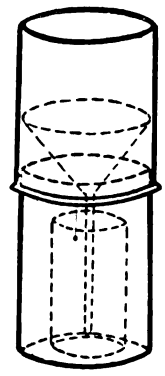

FIG. 1. (RAIN-GAUGE.)

Glaisher's rain and snow-gauge is a cylindrical copper vessel, eight inches in diameter and eighteen inches high. The cylinder is made up of two parts which fit the one on the other as indicated in sketch. Soldered to the upper one is a copper funnel, the plane of whose mouth is about eight inches from the top, and parallel to it. The tube of the funnel reaches nearly to the bottom of the rain-receiving vessel placed on the base of the cylinder. By means of a wooden frame and stakes, the lower part of the cylinder is firmly fixed in the ground, so that the cylinder opening is

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horizontal, and always at the same height above the ground (usually twelve inches).

In a more modern form, due to Professor Nipher, the funnel and receiving vessel are in one piece, the water being drawn off by means of a stop-cock at the bottom. The great improvement introduced by Professor Nipher is the surrounding of the funnel edge by an umbelliform screen of wire cloth, having about sixty-four meshes to the square inch. The advantages of the screen are that it prevents splashing from the ground into the funnel, and (what is very important) breaks up the eddies and currents of air caused by the impact of the wind against the apparatus, which eddies and currents would otherwise carry away many raindrops that should be collected. Another form of protection is that due to Boernstein, who erects round the ordinary gauge, at a distance of two or three feet, an open board fence with its top a little higher than the mouth of the gauge.

(*a*) With an ordinary rain-gauge like Glaisher's, it is found that the deficit of rain caught by the gauge increases with the altitude of the gauge, and roughly speaking, is proportional to the square root of the altitude, provided the gauge is fully exposed to the increase of the wind which prevails at these altitudes. With the Nipher shielded gauge, the rain catch becomes nearly independent of the altitude.

(*b*) The presence of buildings or trees close to the gauge exercises a most marked effect on the rain catch. If the gauge is between the direction from which the prevailing wind comes and the obstacle, be it house, trees or hill, the rain catch is abnormally increased. Thus, in an actual experiment with a number of rain-gauges placed in a line with the direction of the wind, the one about fifty feet from an obstacle of about thirty feet high received 20 per cent. more rain than one on the height, and about 15 per cent. more than one on the same level, distant about 300 feet towards the wind. Generally speaking, unless the area is very level the results from a single gauge would differ widely from the true mean fall for the whole area.

The actual evaporation from land and water at any given place cannot, with the means at present at our disposal, be computed. All one can do is to measure the quantity of water evaporated from a given specific surface of water. This is most readily done by aid of the Piche Evaporimeter. This instrument consists essentially of a glass tube whose upper end is sealed hermetically, whereas the lower end is covered by a horizontal disc of bibulous paper, which is kept wet by absorption from the water in the tube. As the water evaporates, its descent in the tube can be measured, and hence, knowing the cross section, the volume can be calculated. The instrument must be protected from the direct action of the rain. To show the relation between rainfall and the evaporation from this particular surface, it would be necessary to plot two curves having similar abscissæ (*viz.* time). At the middle of every abscissa interval, representing twenty-four hours, set up an ordinate proportional to the rainfall in inches during those hours, and at the same abscissa an ordinate proportional to the fall in inches of the evaporimeter.

If only the relation between evaporation and rainfall was required, it would be sufficient to plot the fall of the evaporimeter against the rainfall. For meteorological purposes, however, the former method would be best.

If a more detailed study of the variations were required, the instruments could easily be made to automatically register the rainfall and evaporation. Thus, in the case of the Piche instrument, it could be suspended from a fixed support by one or more springs, so that as the water evaporated, the tube would move upwards a distance proportional to the loss of water; by providing the tube with a style, a register could be made on a uniformly driven, vertical drum covered with smoked paper, or by means of an electric current passing from the style to specially sensitised paper on the drum.

DESIGN OF CHOKING COIL.—Would you please show how to design a choking coil? Take, for example, a choker for use with an arc lamp requiring 10 amperes at 50 volts; pressure on mains 100 volts, frequency 100 ∽.

A choking coil is a type of transformer with only one winding possessing *low* resistance and *high* inductance. It is employed on alternating current circuits (1) as a protective device for arc lamps connected in series, or (2) as a regulating device for choking or throttling a definite portion of the impressed voltage. The design of a choking coil for either purpose is anything but an easy matter, and no hard-and-fast rule can be given which will apply to the design of a choking coil with an open magnetic circuit. In the case under consideration, the choking coil is for regulation purposes, and should possess constant inductance, so that when placed in series with an arc lamp requiring 10 amperes at 50 volts across a 100-volt circuit, the frequency of which is 100 periods per second, the coil will absorb that portion of the pressure not required by the arc lamp with as little dissipation of energy as possible. On a continuous-current circuit a resistance of 5 ohms would have to be inserted in series with the arc lamp to produce a drop of 50 volts, and this would give rise to a loss of energy equal to that utilised by the lamp, and the working efficiency of the system would be only 50 per cent. By using a choker on alternating current circuits, the loss need not be more than 10 per cent. of the power taken by the lamp.

The form which the choker may take depends upon the special service demanded of the coil, but in all cases the core is laminated and built up of thin sheets of transformer iron. Fig. 1 shows four different types, of which Fig. 1A is of the closed magnetic circuit type, whilst the others possess one or more air-gaps, and are of the open magnetic circuit type. Fig. 1B has an air-gap of short length and definite area of

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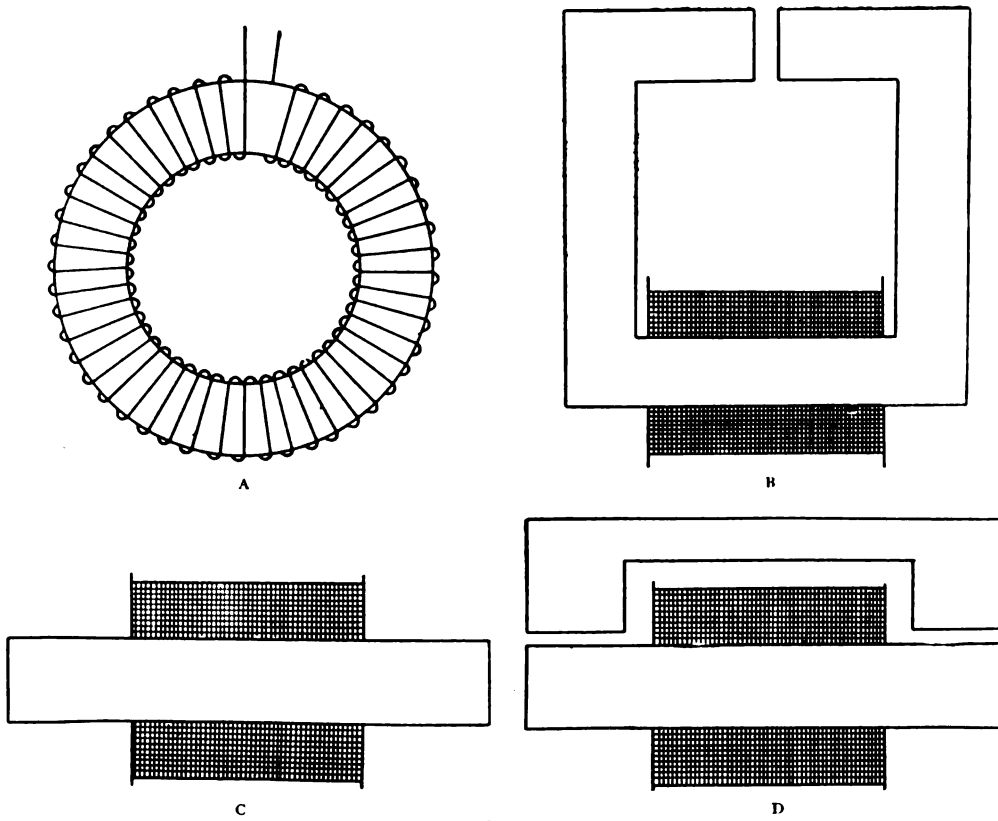

FIG. 1.—(CHOKING COIL.)

cross-section, and for a given current and frequency has a fixed value for its inductance and choking action. When a variable inductance is required, the amount of iron within the coil may be changed by withdrawing the iron core more or less, a process which is possible with the types shown in Figs. 1C and 1D.

The short air-gap type (Fig. 1B) is most suitable for use with an arc lamp when no adjustment of the choked pressure is required, since the presence of the air-gap makes it possible to keep down the cross-section of the core as well as the flux-density B. For this type of choker the following formulæ enable approximate dimensions to be obtained, although the method of design is very largely a *trial and error* process. Assuming that the arc lamp is non-inductive, and that the resistance of the choking coil is small enough to be negligible, the magnitude of the choked pressure is found from the relationship

$$E^2 = e_l^2 + e_c^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which E = impressed E.M.F., e_l = lamp voltage, and e_c = the magnitude of the choked pressure. Consequently,

$$e_c = \sqrt{E^2 - e_l^2} = \sqrt{100^2 - 50^2}$$
$$= 86{\cdot}6 \text{ volts.}$$

And from the theory of the transformer we have

$$e_c = 4{\cdot}44\ NS\ \omega \times 10^{-8} \text{ volts} \quad . \quad (2)$$

from which

$$NS = \frac{e_c \times 10^8}{4{\cdot}44\ \omega} \quad . \quad . \quad . \quad (3)$$

in which N = the magnetic flux, and S = the number of spirals forming the coil. From (3) it is clear that the product NS is of constant magnitude in the case of a choker with constant inductance and a constant frequency. And from the principles of the magnetic circuit we have, for a core of given dimensions and shape,

$$N = \frac{1{\cdot}257\ SI}{\frac{l_i}{A_i \mu_i} + \frac{l_g}{A_g}} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

in which I is the virtual value of the current, l_i, A_i and μ_i are the length, area, and permeability of the iron part of the core, and l_g and A_g refer to the air-gap. It will simplify matters if we fix the length of the air-gap as 0·5 cm., so that the lines of force may be assumed to cross the air-gap along parallel lines, then A_g may be taken equal to A_i and the leakage is a minimum. As regards the flux-density B, it should be noted that the loss by hysteresis is reduced by keeping the value of the flux density small, although it is not necessary to work with

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flux densities as small as with transformers, and in practice from 5,000 to 10,000 lines of force per sq. cm. are suitable values of the maximum value of the flux-density B. It must also be noticed that it will be advisable to work with the maximum value of the flux-density, since the losses due to hysteresis and eddy-currents are proportional to $B^{1.6}_{max.}$ and $B^{2}_{max.}$ respectively; the maximum value of the flux-density is equal to $\sqrt{2}$ (or 1·414) times the virtual value of B.

As a first approximation to fixing the number of turns of wire S required, as well as the dimensions of the core, we may assume that the reluctance of the iron part of the core is so small compared with that of the air-gap that we may neglect it. In this case we have the relation

$$\frac{4\pi}{10} SI \sqrt{2} = B_{max.} \times l_g$$

$\sqrt{2}$ I is the maximum value of the current corresponding to $B_{max.}$, so that taking $B_{max.} = 7000$ we have

$$1{\cdot}257\ S \times (10 \times 1{\cdot}414) = 7000 \times 0{\cdot}5$$

and $$S = 200 \text{ turns}$$

but $$NS = \frac{86{\cdot}6 \times 10^8}{4{\cdot}44\ \omega} \text{ from (3)}$$

$$= A \times \frac{7000}{1{\cdot}414} \times 200$$

in which $\frac{7000}{1{\cdot}414}$ is the virtual value of B, since 86·6 volts is the virtual value of the choked pressure;

$$\therefore \frac{86{\cdot}6 \times 10^8}{4{\cdot}44 \times 100} = A \times \frac{1{,}400{,}000}{1{\cdot}414}$$

$$\therefore A = 20 \text{ sq. cms.}$$

The volume of the iron forming the core can be best obtained by fixing the permissible core losses due to hysteresis and eddy-currents, and if these losses be limited to 10 per cent. of the power absorbed by the arc lamp (*i.e.*, 10 per cent. of 500 watts), we have W = 50 watts. But the iron losses in a transformer are given by the relation,

$$W = V \{\eta\, \omega\, B^{1.6}_{max.} \times 10^{-7} + t^2 \omega^2 B^{2}_{max.} \times 10^{-16}\} \text{ watts} \quad . \quad . \quad . \quad (5)$$

in which V is the volume of the iron in cu. cms.; η = ·0024 is the hysteresis coefficient; t = thickness of the plates in mils, a suitable value for which is 15 mils. By substitution we have

$$50 = V \left\{ \frac{{\cdot}0024 \times 100 \times 7000^{1.6}}{10^7} + \frac{15^2 \times 100^2 \times 7000^2}{10^{16}} \right\}$$

$$= 0{\cdot}045\ V;$$

$$\therefore V = \frac{50}{0{\cdot}045} = 1100 \text{ cu. cm.}$$

But the area of cross-section of the core is 20 sq. cms., therefore the mean length of the iron part of the magnetic circuit is

$$l_i = \frac{1100}{20} = 55 \text{ cms.}$$

At this stage we may test the accuracy of the results thus obtained by applying formula (4); thus—

$$N_{max.} = \frac{1{\cdot}257\ SI\sqrt{2}}{\frac{l_i}{A_i \mu_i} + \frac{l_g}{A_g}}$$

$$= \frac{1{\cdot}257 \times 200 \times 10 \times 1{\cdot}414}{\frac{55}{20 \times 2220} + \frac{{\cdot}5}{20}}$$

$$= 135400$$

2220 is the permeability of sheet iron for a flux density of 7000.* Again, $N_{max.} = 7000 \times 20 = 140{,}000$, and as the two values are of the same order of magnitude, the values obtained may be accepted as being satisfactory, although in practice slight corrections would perhaps be necessary. The next point to consider is the determination of the dimensions of the core, and the size of wire to use. As the cross-section of the iron forming the core is 20 sq. cms., we may take 100 plates, which gives a depth of 3·8 cms., since the thickness of each plate is 15 mils = 0·038 cm., and the width of the plate will be $\frac{20}{3{\cdot}8} = 5{\cdot}27$ cms. Having decided upon a rectangular shape for the core, the dimensions will be those shown in Fig. 2.

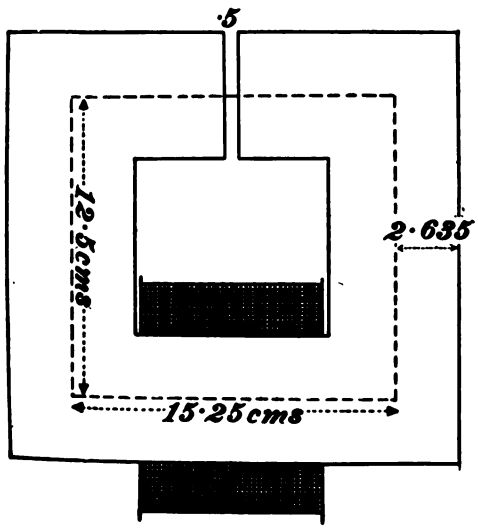

FIG. 2.—(CHOKING COIL.)

As regards the gauge of the wire, it will be convenient to take 1000 amperes per sq. inch as the current density, so that for 10 amperes the cross-sectional area of the wire will be $\frac{1}{100}$ sq. inch; and as a No. 11 S.W.G. wire has an area of 0·01057 sq. inch, and a diameter of 0·116 inch, this wire will do nicely, and allowing 14 mils additional for the double cotton covering, the diameter of the insulated wire will be 0·13 inch. With a length of 10 cms. (nearly 4 inches) available for the wire, 30 turns per layer may be put upon the core, so that there will be 6 layers of 30 turns and one layer of 20 turns.

* See "Magnetisation Curve," TECHNICS, page 180, Vol. I.

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RADIAL VANE PUMP.—Determine the horse-power which will be required to drive a radial vane pump which delivers 20,000 gallons of water a minute; the pump runs at 80 revolutions a minute, and is 10 feet in diameter. What would the efficiency be on a lift of 20 feet?

If the radius of the pump disc is expressed by R (feet), and its speed by N (revolutions per minute), then

$\frac{2\pi R N}{60} = \frac{\pi R N}{30}$ = the tangential velocity of the rim of the disc, in feet per second, and

$\frac{\pi N}{30} = \omega$ = angular velocity of the disc in radians per second.

If the pump delivers G gallons of water per minute,

$\frac{10 G}{60} = \frac{G}{6}$ = lbs. of water delivered per second.

Since the vanes on the disc are radial, the water as it leaves the disc has the same tangential velocity as the disc itself.

Hence the kinetic energy of the water delivered per second

$$= \frac{W v^2}{2g}$$
$$= \frac{G}{12g} \times \left(\frac{\pi N}{30}\right)^2 \times R^2$$
$$= \frac{G \omega^2 R^2}{12g},$$

W representing the weight of water in pounds, and v its tangential velocity in feet per second.

This does not express the whole of the energy received by the water in its passage through the pump; for as any portion of water is whirled around it exerts centrifugal force upon the water in contact with it, in a direction outward from the centre of revolution. Also, the portion of water considered moves outward whilst exerting this force, and therefore does work upon the water against which it presses. Assuming the water to enter the pump at the centre of the disc, then the work performed by W pounds of water during its journey along the vane may be deduced from the diagram.

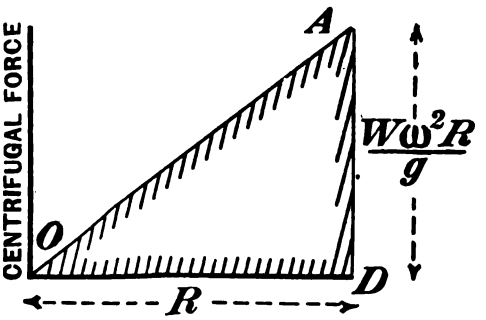

FIG. 1.—(RADIAL VANE PUMP.)

Horizontal distances from O represent the distance of the quantity of water considered from the centre of revolution, and along the vertical axis the corresponding value of the centrifugal force is set off to scale. Then the curve (OA) obtained by plotting these values will be straight, because $\frac{W \omega^2}{g}$ is a constant.

In the same way that an indicator diagram represents work done, the triangular area O A D represents the work done by W pounds of water in moving at a uniform velocity from the centre to the outside of the disc.

The work area O A D $= \frac{W \omega^2}{2g} \times R^2$

Substituting for W, the actual quantity of water passing along the vanes per second, *viz.*, $\frac{G}{6}$ pounds,

$$\text{Area O A D} = \frac{G \omega^2}{12g} R^2.$$

The kinetic energy of the water due to its tangential velocity, and the energy it has exerted by pressure in a radial direction, must both have been derived from energy supplied to the pump, and as the expression for either of these quantities is $\frac{G \omega^2 R^2}{12g}$, it follows that the total energy per second given to the water by the pump is twice the amount of the kinetic energy, that is :—

$$\text{Total energy supplied per second} = \frac{G \omega^2 R^2}{6g}.$$

From this the horse-power required to drive the pump may be deduced, for the energy supplied per minute $= 60 \times \frac{G \omega^2 R^2}{6g}$.

Hence, $$\text{H.P.} = \frac{G \omega^2 R^2}{3300 g}.$$

Substituting numerical values,

$$\text{H P} = \frac{20{,}000 \times (8{\cdot}37)^2 \times 5^2}{3300 \times 32} = 332.$$

If all the energy received by the water from the pump were converted into potential energy, then in every second, $\frac{G}{6}$ pounds would be lifted to a height of H feet, such that

$$\frac{G}{6} \times H = \frac{G \omega^2 R^2}{6g}.$$

Hence, $$H = \frac{\omega^2 R^2}{g}.$$

Substituting numerical values,

$$H = \frac{(8{\cdot}37)^2 \times 5^2}{32} = 54{\cdot}7 \text{ feet.}$$

H is the height to which the water would be lifted if all the energy received were usefully employed, and therefore if the water is delivered at a lesser height (h), the hydraulic efficiency of the pump $= \frac{h}{H}$.

Taking the value of h as 20 feet, this efficiency $= \frac{20}{54{\cdot}7} = 36{\cdot}6$ per cent.

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SPIRAL.—Draw a geometrical tangent to an Archimidean Spiral, and give proof.

The characteristic property of this spiral is that the increase of the radius between any two points of the spiral is proportional to the angle ϕ between these radii, or

$$r - r_1 = a\phi$$

ϕ being in circular measure.

If θ is the angle which r makes with some fixed line in the plane, and θ_1 the angle r_1 makes with the same line, then $\phi = \theta - \theta_1$, and

$$r - r_1 = a(\theta - \theta_1).$$

Moreover, if the fixed line be chosen so that $r_1 = a\theta_1 = 0$ (*i.e.*, that the angle and the radius vanish at the same time), we have the simple equation

$$r = a\theta$$

for the spiral.

We may then suppose the spiral generated by the end point of a revolving rod of variable length, the angular speed of the rod being uniform, and its increase in length also uniform. Thus, we may take the angle turned through by the rod and its length to be proportional to the time; in symbols

$$\theta = kt$$
$$r = akt,$$

k being any convenient number (of course, k must have the dimension of the reciprocal of a time).

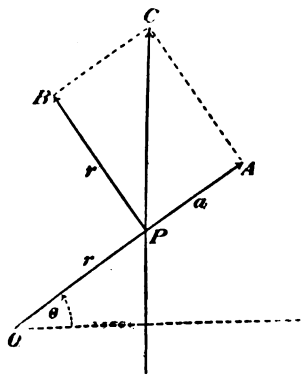

FIG. 1.—(SPIRAL.)

The angular speed is then k, and the speed along the radius is ak.

For a point moving along a curve, the direction of motion is along the tangent to the curve at that point; hence the problem is simply to find the direction of the resultant velocity due to uniform circular and radial velocities. Let P be the point at which the tangent has to be drawn, then P has a speed $\perp$ to OP of magnitude rk, and a speed along OP of magnitude ak.

Hence, taking $k = 1$ for convenience set off

$$PB = r, \perp \text{ to OP},$$

produce OP to A so that PA = a, complete the rectangle PACB, and join PC, then PC is the direction of the resultant velocity and the tangent to the curve at P.

We see from this construction that the angle between the tangent and the radius vector is such that its tangent (trigonometrical) is given by $\frac{r}{a}$. An easy application of the calculus gives another proof of this property.

NITROSO.—With respect to your answer to my previous query regarding the production of potassium-iron heptanitroso-sulphide, published in the August number of "Technics" (Vol. II., p. 195), I should be much obliged if you would enlighten me on one point. You say, "the mixture is kept hot until a distinct greenish red precipitate begins to form, when it is filtered quickly." In my experiments, as soon as the iron solution was added to the other, a violent reaction took place accompanied by the evolution of nitrous fumes. Why is this?

We suggest that our correspondent should add the iron solution by means of a long capillary funnel made by drawing out a test-tube; it will then be possible to allow the two solutions to come gradually into contact at the bottom of the containing vessel, and the nitrous fumes will thus have better opportunity to become reabsorbed; it is not easy entirely to avoid loss, in any case.

The liquid should be kept hot after the addition has been completed and until the greenish-red precipitate has formed: the time required varies considerably in practice.

To obtain potassium ferronitroso-sulphide ("potassium iron tetranitroso-sulphide") $KFe(NO)_2S.2H_2O$, the "heptanitroso" (ferrinitroso) compound is warmed on the water bath with several times its weight of dilute potassium hydroxide; the sparingly soluble residue being washed rapidly with water and dried in a vacuum, in presence of lime and sulphuric acid as dessicating agents. It is difficult to obtain this compound pure, as it easily passes back again to the ferrinitroso-sulphide.

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TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

DEAR SIR,—I would like to draw the attention of Mr. Edser to a portion of his article, in the November number of TECHNICS, dealing with the future of electric heating. He says: "Electric cooking utensils compare very favourably with the ordinary fire-heated appliances, in thermal efficiency." I enclose a calculation showing that, if no heat were radiated away, it would cost about 4·8 pence to raise a gallon of water from freezing to boiling point. This sum would be probably materially increased owing to radiation. Now, as the operations of cooking demand the heating of much water, it follows that this method must turn out somewhat costly. I have also shown that about 45 lbs. of coal may be bought for this sum, and I should imagine that a good many gallons could be similarly heated with this in the ordinary grate. Of course, there is the large waste of heat and expense of preparation to be accounted for, but nevertheless the ordinary fire must be much more economical. The efficiency of the fire grate might become quite high with large (cooking) loads, but that of the electrical method is at its best in the calculation. This result may prove of interest to those about to instal electric cooking apparatus, and it appears to be generally overlooked.

I am, Sir,
Yours sincerely,
W. L. TURNER.

Purley Chase,
Atherstone.

[An error occurs in the working forwarded by Mr. W. L. Turner, which materially affects the calculated cost of boiling a gallon of water by electrical means. The correct working is as below :—

1 gallon = 10 lbs. = 4,540 grams of water.

To heat 1 gallon of water through 100° C. requires

$4{,}540 \times 100 = 4{\cdot}54 \times 10^5$ gram-calories.

Equivalent in energy

$= 4{\cdot}54 \times 10^5 \times 4{\cdot}2 \times 10^7 = 19{\cdot}1 \times 10^{12}$ ergs.

1 Board of Trade unit (B.T.U.) = 1 kilowatt hour = $3{,}600 \times 10^{10}$ ergs;

∴ to boil 1 gallon of water requires

$(19{\cdot}1 \times 10^{12}) \div (36 \times 10^{12})$ B.T.U.'s

$= 0{\cdot}53$ B.T.U.

Thus, with electrical energy at 2½d. per B.T.U., cost of boiling 1 gallon of water = 1·3*d.* —EDITOR.]

To the Editor of TECHNICS.

DEAR SIR,—Permit me to point out that there is a slight error in several of the *accelerations* recorded in Fig. 13, A.B.C. . . . F, on pages 426-7 : article dealing with Heavy Electric Traction :—

2·07 should be 2·05 feet per second per second.
2·65 should be 2·64 feet per second per second.
. . .
2·94 should be 2·93 feet per second per second.
3·82 should be 3·81 feet per second per second.
4·42 should be 4·40 feet per second per second.

This last error is repeated in Table III., page 432, last column.

I feel sure that Messrs. Parshall and Hobart will be pleased to have these inaccuracies altered, as the results embodied in their articles will undoubtedly be taken, and referred to, as "standards" by many electrical engineers and teachers of electrical engineering.

I also wish to take this opportunity of making a suggestion. Some engineers prefer to check the results they obtain from "standard curves," by a rapid calculation where possible. This being so, I venture to suggest the following "*General Form*" for the equation for calculating the acceleration interval for a schedule run under given conditions :—

$$x^2 - \mathrm{T}.x + \frac{\mathrm{A}}{b} = 0$$

where—

x = acceleration interval in seconds.
T = total time from start to stop in seconds.
A = distance in feet from start to stop.
b = acceleration in feet per second per second.

The equation in the above form is easy to remember, and the amount of calculation is reduced to a minimum by adopting some such standard form. The above letters are used with the meanings here given, in the articles by Messrs. Parshall and Hobart. Personally I prefer the following letters, as they suggest what they are intended to signify :—

Small t = time of acceleration in seconds.
Capital T = time for complete run in seconds.
Capital D = distance of run in feet.
Small a = acceleration in feet per second per second.

The equation then becomes :—

$$t^2 - \mathrm{T}.t + \frac{\mathrm{D}}{a} = 0.$$

Yours faithfully,
S. IRWIN CROOKES.

Battersea Polytechnic, London, S.W.
December 10th, 1904.

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RESULTS OF NOVEMBER COMPETITIONS.

ELECTRIC TRACTION.

FIRST PRIZE, £1 10s.—Albert Beeston, 45, Beech Avenue, Sherwood Rise, Nottingham.

SECOND PRIZE, £1.—J. D. W. Ball, 71, Brooklyn Street, Crewe.

THIRD PRIZE, 10s.—E. G. Kennard, Manor Cottage, Lee, S.E.

HONOURABLE MENTION :—W. E. Ayres; Harold Slicer; George Keinath; D. Fulton; T. M. Barlow; H. A. Stewart; R. Proudlove; C. H. Finnis; Albert H. Marshall.

MECHANICAL ENGINEERING.

PRIZE, £3.—Divided equally between two competitors: Jesse Haigh Baxter, 17, Woodland Road, Gorton, Manchester; Harold Slicer, 37, Crofton Road, Camberwell, S.E.

SPECIAL HONOURABLE MENTION: H. G. Lester; Arthur Gadd.

ELECTRIC HEATING.

PRIZE, £3.—S. Irwin Crookes, 113, Heythorp Street, Southfields, S.W.

SPECIAL HONOURABLE MENTION: Albert E. Jepson; William B. Clarke.

HONOURABLE MENTION: John Clarke.

COLOUR PHOTOGRAPHY.

FIRST PRIZE, £1 10s.—Ernest G. Beach, 100, Cowley Road, Brixton, S.W.

SECOND PRIZE, £1.—John R. McIlwraith, 4, Harcourt Buildings, Temple, E.C.

THIRD PRIZE, 10s.—Oswald J. Harding, 79, Cecil Avenue, Bradford.

SPECIAL HONOURABLE MENTION: Harry W. Hilliar; R. T. Hancock; Robert H. Buckie; Harry F. V. Little; J. C. M. Garnett; E. H. Higgins; D. E. Synan; George S. Whitby; James Augustus Robertson; George Lees; Wm. D. Ross; Ernest J. Taylor; Edgar P. Hedley; B. J. Eaton; Gerald Henniker; Harold Slicer; Ellis Clayton; H. A. Stewart; S. Irwin Crookes; Ernest W. Sanders.

HONOURABLE MENTION: Alfred Howard Garner; W. E. Ayres; Douglas Wait; D. Fulton; Edwin Royce; Frederick Hickey; H. H. Francis Hyndman; Robert Ure; W. H. Grinsted; F. C. A. H. Lantsberry; G. F. Harrison; Stanley E. Gritton; Fred. Scholefield.

TEXTILE INDUSTRIES.

FIRST PRIZE, £2.—Fred. Southworth, 18, High Street, Bolton, Lancs.

SECOND PRIZE, £1.—Robert Fish, 47, Edward Street, Farnworth, near Bolton.

SPECIAL HONOURABLE MENTION: J. E Tytler; Frederic Stones.

ELECTRO-MAGNETIC THEORY.

PRIZE, £5.—Divided equally between two competitors: A. G. Lee, Fairfield, Eaton Park Road, Winchmore Hill, N.; H. H. Francis Hyndman, 27, Pembroke Square, Kensington, W.

SPECIAL HONOURABLE MENTION: Charles Percy Hines; Jas. A. Robertson; Samuel Lees; Arthur C. Beach; Harold Slicer; S. Irwin Crookes.

HONOURABLE MENTION: W. Tolerton; H. A. Stewart.

THEORY OF STRUCTURAL DESIGN.

FIRST PRIZE, £3.—H. Rigby, 129, Cavendish Road, Balham, S.W.

SECOND PRIZE, £2.—D. E. Synan, 36, Cecil Street, Limerick.

SPECIAL HONOURABLE MENTION: Arthur Gadd.

HONOURABLE MENTION: Harold Slicer; S. Irwin Crookes.

RESULTS OF DECEMBER COMPETITIONS.

CHEMICAL ENGINEERING.

PRIZE, £3.—B. J. Eaton, 37, Belitha Villas, Barnsbury Park, N.

SPECIAL HONOURABLE MENTION: Harry Hutchinson; Rowland L. Goold; S. Irwin Crookes.

HONOURABLE MENTION: Harold Slicer.

MECHANICAL ENGINEERING.

PRIZE, £3.—Divided equally between two competitors: Harold Slicer, 77, Bellenden Road, Peckham, S.E.; A. E. Linnell, 11, Brewery Street, Chesterfield.

SPECIAL HONOURABLE MENTION: H. A. Stewart; S. Irwin Crookes.

HONOURABLE MENTION: Edwin Roscoe.

COTTON SPINNING.

PRIZE, £3.—A. W. Brierley, 9, Belgrave Street, Meanwood, Rochdale.

SPECIAL HONOURABLE MENTION: J. E. Tytler; Harold Taylor.

HONOURABLE MENTION: Robert Marcroft; S. Irwin Crookes; Charles Barnshaw.

ELECTRICAL ENGINEERING.

PRIZE, £3.—Joseph Rafton, Knowsley Park, near Prescot, Lancashire.

SPECIAL HONOURABLE MENTION: Cecil Howard; H. A. Stewart; H. G. Trust.

HONOURABLE MENTION: S. Irwin Crookes; John Wilson.

ELECTRO-MAGNETIC THEORY.

FIRST PRIZE, £3.—Mildred E. Macken, 52, West Side, Wandsworth Common, S.W.

SECOND PRIZE, £1 10s.—Samuel Lees, 1, Trafalgar Street, Broughton, Manchester.

THIRD PRIZE, 10s.—Charles P. Hines, The Grammar School, Dartford, Kent.

SPECIAL HONOURABLE MENTION: Thos. H. Collett; G. Reucastle Grieve; B. J. Field; John P. Dalton; S. Irwin Crookes.

HONOURABLE MENTION: R. H. Greaves; Hilton Grace; Joseph W. Beswick; H. H. Francis Hyndman.

THEORY OF STRUCTURAL DESIGN.

FIRST PRIZE, £3.—Percy J. Robinson, Engineer's Dept., District Offices, Hamilton, N.B.

SECOND PRIZE, £1 10s.—D. E. Synan, Engineer's Office, G. S. & W. Railway, Limerick.

THIRD PRIZE, 10s. — Harold Slicer, 77, Bellenden Road, Peckham, S.E.

SPECIAL HONOURABLE MENTION: Arthur Gadd.

HONOURABLE MENTION: J. D. W. Ball.

The name of the TECHNICS Prizeman will be announced in the March number.

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PERSONAL ITEMS.

AN Optical Convention will be held in London at a date towards the end of May, 1905, in the buildings of the Northampton Institute, Clerkenwell, E.C., which have been kindly placed at the disposal of the Committee by the Governing Body. The main object of the Convention is to bring into close sympathy and co-operation men interested in optical matters, from all sides of the question—theoretical, practical and commercial. This it is proposed to do by holding a series of meetings for papers and discussions on optical questions. A "Papers" Sub-Committee has been appointed, with Prof. S. P. Thompson as Chairman, and Mr. S. D. Chalmers as Secretary. This Sub-Committee is considering the subjects of the papers which should be brought before the Convention, and suggestions sent to the Secretary as to papers or subjects for discussion will be gladly welcomed. It has also been decided to organise an Exhibition, of a scientific character, of instruments manufactured in this country, with a view to showing the great progress recently made, and of stimulating further efforts. A unique opportunity will thus be afforded of bringing optical instruments to the notice of manufacturers, of scientific men, and of the public.

IN reviewing Barnard and Child's "New Geometry for Schools" (January TECHNICS, page 91), the price of this book was given as 9*s.* net, instead of 4*s.* 6*d.* We must apologise for this error.

A LIMITED number of Teacherships-in-training, tenable at the Metropolitan School of Art, Dublin, will be open for competition at the beginning of the Session 1905-6. Candidates must forward Form S. 3, properly filled up, so as to reach the offices of the department not later than April 29th. Form S. 3 may be obtained, after February 1st, 1905, upon application to the Secretary, Department of Agriculture and Technical Instruction for Ireland, or to the Registrar, Metropolitan School of Art, Kildare Street, Dublin.

WE have received a copy of "Phillips's Machinery Register," a monthly publication which has now been issued for thirty-one years. It contains a comprehensive list of good second-hand and new machinery of every description for sale. It also has an "Electrical and Autocar Supplement" connected with it. Both catalogues should prove useful to those looking out for bargains in good second-hand plant, especially electrical plant and automobiles.

THE 600-H.P. Westinghouse steam turbo-generator, installed in the Palace of Machinery at the St. Louis Exposition, was shut down on Friday, December 2nd, after a continuous run of 3,962 hours. It was found to be in perfect condition, and there were no signs of wear, the bearings still retaining the tool marks as they had come from the shops. During the five-and-a-half months that the unit was in operation, it supplied current for light and power throughout the Westinghouse exhibits in the Palaces of Machinery, Electricity, and Transportation.

THE Council of the Iron and Steel Institute will shortly proceed to award a research scholarship, or scholarships, founded by Mr. Andrew Carnegie. Candidates must be under thirty-five years of age, and must apply to the Secretary of the Institute, on a special form, before the end of February. The object of the scholarships is to provide post-graduate students with a means of conducting researches in the metallurgy of steel, and allied subjects.

WE have received an interesting pamphlet on "The Detection of Adulterants in Sumach by Microscopical Examination," by M. Chas. Lamb, F.C.S. The author finds that when the sumach leaf is heated in a 50 per cent. solution of nitric acid, its cuticle swells up and forms what is called "sumach wreck." Other leaves commonly used to adulterate the sumach are not similarly affected, so that their presence can be easily detected.

TO what extent modern well-made electrical machinery will stand ill usage is strikingly demonstrated by the following incident that occurred recently in the United States. The New England Building at Cleveland, Ohio, is electrically lit throughout by a plant consisting of three Westinghouse 62 5-k.w. engine type generators, installed in the basement. Through some carelessness, this building recently became the scene of a rather serious fire. The heat to which the machines were subjected was sufficient to completely burn away the insulation on the outside of the field coils, and for an hour they were played upon by six hose-pipes; but within an hour of the extinction of the fire the first of these machines was carrying its full load, and another followed suit in a short time—the two dealing with the entire lighting of the building that, under normal conditions, was negotiated with three machines.

THE Rev. Father O'Toole, of Black Rock College, Dublin, has invented a very useful form of extensimeter for measuring the coefficient of linear expansion of metal rods. Unlike other instruments designed for the same purpose, that due to Father O'Toole utilises a sensitive level to indicate the expansion of the rod: one extremity of the level is supported on the upper end of the rod experimented on, and the other extremity of the level can be raised or lowered by the aid of a micrometer gauge. By this means an instrument is obtained which, while possessing considerable accuracy, can be sold at a moderate price. The instrument is made by Philip Harris & Co., Ltd., 144, Edmund Street, Birmingham.

A COURSE of ten lectures on "Enzymes" will be delivered at University College, London, by Dr. W. M. Bayliss, F.R.S., the first lecture being on January 18th. These lectures are open to all internal students of London University, and also to medical men on presentation of their cards.

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ERNST ABBE.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. III. MARCH, 1905. No. 15.

PROGRESS OF SCIENCE AND TECHNOLOGY.

THE death of Professor Ernst Abbe, which occurred early in January, has left the world the poorer by the loss of an eminent man of science whose life was devoted to the furtherance of technical progress. Professor Abbe will long be remembered, not only as an original investigator whose researches gave rise to the development of an important manufacturing firm, but also as a warm-hearted philanthropist who lived to witness the success of a scheme of social reform for which he was alone responsible. To-day, the Carl Zeiss "Stiftung" (or trust) forms the most fitting monument to the technical ability and philanthropic zeal of Abbe; the English translation* of a book from the pen of Professor Auerbach opportunely gives an authentic account of that most remarkable technical and social enterprise.

Ernst Abbe

Ernst Abbe was born on January 23, 1840; his father was a foreman in a spinning mill at Eisenach. After studying at the universities of Jena and Göttingen, the young man became a teacher of mathematics and physics, and in 1870 was appointed as extraordinary professor at the University of Jena. At this time Abbe had already become associated with Carl Zeiss, and his subsequent biography is little more than a history of the development of the Zeiss firm.

In 1846 a small workshop for the manufacture of optical and other philosophical instruments was opened, near the University at Jena, by Carl Zeiss. Zeiss was the son of a toy-shop proprietor, and had served his apprenticeship as a mechanical engineer. The optical instruments, mostly microscopes, which Zeiss at first manufactured were neither better nor worse than those made elsewhere; but financial success attended his efforts, and most men in his place would have been content to let well alone and to enjoy a modest prosperity. Zeiss, however, was of a different cast; he was ambitious to improve the design of optical instruments, and devoted his spare time to study in order to fit himself for this task. Very soon it became apparent to Zeiss that he would have little chance of acquiring the knowledge which he needed; but though his immediate wishes were thus frustrated, the studies which he had undertaken had not been without value, for they led him to appreciate the necessity of the knowledge which he had sought, but failed to obtain.

At this juncture Zeiss met Abbe, who was a mathematical physicist, unacquainted with the practical aspect of opto-technics. As a result of many consultations and discussions, these two men decided to devote their futures to the improvement of optical apparatus. This was a bold step for either of them—especially for Zeiss, to whom a failure in the new undertaking would mean financial ruin. It was clearly realised by both Abbe and Zeiss that no immediate success could be hoped for; indeed, the first efforts to bring optical design and construction under the exact rule of science could scarcely be hoped to give such good results as the rule-of-thumb methods previously employed; for these latter were the result of a vast amount

* The Zeiss Works and the Carl-Zeiss Stiftung in Jena: their Scientific, Technical, and Sociological Development and Importance popularly described. By Felix Auerbach. Translated from the Second German Edition by Siegfried Paul and Frederic J. Cheshire. pp. viii. + 146, with 86 illustrations. (London: Marshall, Brookes and Chalkeley, Limited, 1905.) Price 2s. 6d. *net*.

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of experience, even if this was of a blundering nature. What was aimed at, however, was ultimate success; and to this end long investigations were undertaken with a view to determine what might be done if glass of particular properties could be obtained. As a result, the kind of glass that was required was definitely determined, and in a report on the South Kensington Loan Exhibition (1876), Abbe wrote: "The future of the microscope, as regards further improvements in its dioptric qualities, seems to lie chiefly in the hands of the glass-maker." The difficulty was, however, to find a glass-maker who would devote time and labour to the scientific study of glass manufacture; this was only natural, as the amount of optical glass used in the whole world is not great, and therefore no considerable financial profit could be anticipated, even if the required glasses should at last be produced.

Abbe's report fell into the hands of Dr. Otto Schott, a glass-maker of Witten in Westphalia. After communicating with Abbe, Schott undertook, in 1881, a series of researches with the object of determining the relation between the optical properties of glass and its chemical constitutions. In 1882 Schott removed to Jena: aided by a grant from the Prussian Minister of Education, the experiments were satisfactorily concluded, and an almost ideal microscope became a practical possibility. Further, the financial success, which could scarcely have been hoped for, was nevertheless realised; for in the systematic study of glass manufacture valuable results had been obtained, which led to the wholesale production of glass with properties which were in requisition on a large scale. To-day everyone is familiar with the usefulness of Jena glass, not only in the laboratory, but in the arts.

A detailed account of Abbe's researches in connection with the microscope would here be out of place; we must pass over several years of steadily increasing success to the Zeiss firm, until we come to 1888, at which date Zeiss died, and the whole of the management of the firm soon fell on Abbe. Abbe had not worked with the object of accumulating wealth, and when wealth came to him he put it aside. The firm was converted into the "Carl Zeiss Stiftung"—a co-operative association in which the profits are shared amongst the workers, and elaborate arrangements are made to provide for the sick and aged. According to this arrangement, no one connected with the "Stiftung" can receive a salary exceeding ten times the average yearly earnings of a workman of twenty-four years standing, who has been at least three years with the firm; Abbe himself, after the formation of the Stiftung, received only the salary specified above. The working day is fixed at eight hours, and it has been found that in this time a worker does, on an average, 4 per cent. more work than in a nine hours day.

Enough has, we hope, been said to justify the statements made at the head of this notice; we may now proceed to the description of a few novel and interesting instruments made by the Carl Zeiss Stiftung.

Progress in Optics

The Zeiss optical works at Jena have attained a position of such importance in the technical world, and have effected so many important improvements in the design and manufacture of optical instruments, that Professor Felix Auerbach's account of these works is of peculiar interest. As the result of patient researches, new kinds of glass have been produced; by the use of these, many of the most troublesome defects of telescopes and microscopes have been minimised, and even eliminated. Further, by the ingenious applications of optical principles, many instruments have been brought to a state of perfection which has never before been reached, and some essentially novel instruments have been produced. At present we must confine our attention to improved forms of telescopes introduced by the Zeiss works.

The object glass of a telescope forms an inverted image of distant objects in its focal plane. When the telescope is used for astronomical purposes, the image may be viewed directly by the aid of an eye-piece, which essentially serves the purpose of a magnifying glass; in this case, the inversion of the image is of no consequence. The length of such a telescope is, however, very considerable, for the distance from the object glass to the real image which it forms is equal to the focal length of the object glass, and the distance from this image to the eye-piece lens must be equal to the focal length of the eye-piece; consequently the length of the telescope is equal to the arithmetical sum of the focal lengths of the object glass and eye-piece.

For observing terrestrial objects, it is essential that the image seen shall be erect; to secure this end two different arrangements have been adopted.

In the Galilean telescope, the eye-piece lens is divergent; it is placed in such a

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position that the rays from the object glass fall on it before they form a real image, with the result that the real image is not formed, and the image seen is virtual and erect; in this case the length of the telescope is equal to the arithmetical difference between the focal lengths of the object glass and eye-piece, so that it is less than that of an astronomical telescope. This arrangement has been very generally used in the construction of opera-glasses. In recent years these have nearly always been made in the binocular form, and indeed the name "opera glasses" has become so closely associated with this form that it is curious to reflect that fifty years ago opera-glasses were monocular, as can be seen, for instance, in some illustrations of Thackeray's "Vanity Fair." The image formed by the Galilean arrangement is, however defective and of unequal brightness, so that it is never used where high magnification is required.

FIG. 1. OPTICAL SYSTEM, ZEISS FIELD GLASS.

In the ordinary terrestrial telescope, a special lens or lens system is employed to render the observed image erect. If an object is placed at a distance from a convergent lens equal to twice the focal length of the latter, then an inverted image of the same size as the object will be formed on the opposite side of the lens, at a distance from this equal to twice its focal length. The distance from object to image is equal to four times the focal length of the lens: this is the smallest distance between an object and its real image obtainable with a given convergent lens. In the terrestrial telescope the real inverted image formed by the objective serves as the object for the erecting lens; the distance from the inverted image to the erecting lens is equal to twice the focal length of the latter; the resulting image, formed on the opposite side of the lens, is once more inverted, so that it agrees with the object, and can finally be viewed by the aid of a suitable eye-piece. A terrestrial telescope made on this system does not suffer from the defects associated with a Galilean telescope; but the length of the terrestrial telescope is necessarily very great, since it must exceed that of an astronomical telescope by four times the focal length of the erecting system.

IN 1875 Prof. Abbe constructed a terrestrial telescope on a new plan, without using any erecting lens system. The length of this telescope was about one-third of the length of an astronomical telescope of the same magnifying power. The principle on which this result was obtained depends on the fact that, although the distance from the object glass to the image, *measured along the rays which form the image*, must be equal to the focal length of the objective, yet the rays need not proceed in a continuous straight line, but may be reflected backwards and forwards by a suitable arrangement of mirrors. In practice it has been found that better results may be obtained by using reflecting prisms in order to change the path of the rays, since silvered mirrors continually need re-polishing.

Zeiss Field Glasses

The optical arrangement adopted in the Zeiss prismatic field glasses is shown in Fig. 1. The arrow indicates a ray from the object; after passing through the object glass, this ray is twice internally reflected by a rectangular prism, its direction being thus reversed; two more reflections by a second rectangular prism once more reverse the direction of the ray, which then proceeds parallel to its original direction, and passes through the eye-piece to the eye of the observer. Thus the instrument is reduced to about one-third of the length that would be necessary if the reflecting prisms were absent. The prisms also serve to render the final image erect. To understand their action in this respect, we may refer to Fig. 2. It will be seen that if two parallel rays in a vertical plane are twice reflected by a rectangular prism of which the axis is horizontal, then the ray which was originally the upper, will finally be the lower of the two: this would produce a partial inversion of the image, in so far as its upper would become its lower end, and *vice versâ*. It is also, however, necessary to produce a lateral inversion, the right side of the image being transformed to the left side, and *vice versâ*; this end is accomplished by placing the second prism with its axis at right angles to that of the first one (Fig. 1), when one prism effects a longitudinal, and the other a lateral inversion of the image. This point may be made clearer by reference to Fig. 3, which shows the isometric pro-

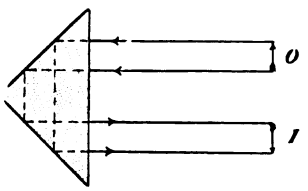

FIG. 2.—TO EXPLAIN INVERSION PRODUCED BY DOUBLE REFLECTION IN RECTANGULAR PRISM.

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jection of two rays reflected by four rectangular prisms. It is clear that each pair of prisms can be combined without altering the final result. Fig. 4 shows the optical arrangement, and Fig. 5, the general appearance, of the Zeiss binocular field glasses.

The Stereo-Telescope

ANOTHER novel instrument due to the Zeiss firm is the stereo-telescope. As will be seen from Fig. 6, the telescope consists of two tubes mechanically connected by means of a hinge. The light enters that end of either tube which is remote from the hinged connection: its initial direction is perpendicular to the axis of tubes, but after being once reflected

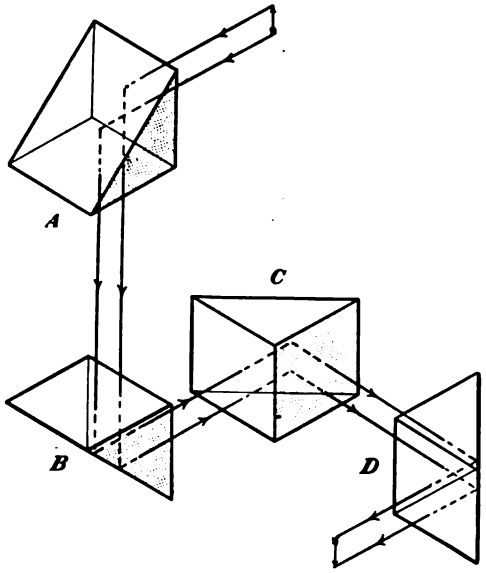

FIG. 3.—ISOMETRIC PROJECTION OF TWO RAYS REFLECTED INTERNALLY BY FOUR PRISMS.

by a rectangular prism, it follows the direction of the axis of the tube till, near the hinged end, it is three times reflected by means of a combination of two rectangular prisms. The path of the rays will be easily understood on reference to Fig. 7. It is obvious that this form of telescope may be used to look round an obstacle; a more important property is that an enhanced stereoscopic effect is produced.

Let a hand be held edgeways in front of the face; then it can easily be observed, by closing first one eye and then the other, that the two eyes gain very different views of the hand. When the hand is seen by the aid of both eyes simultaneously, the different images

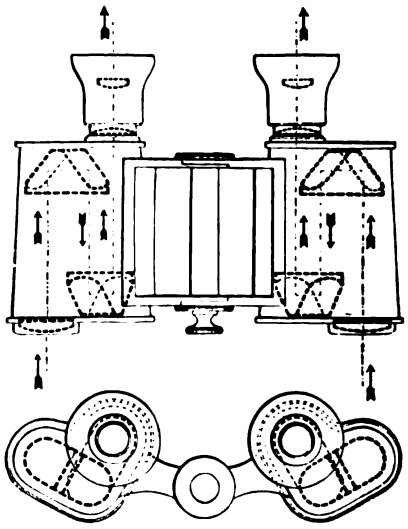

FIG. 4.—SECTIONAL PLAN AND ELEVATION OF ZEISS FIELD GLASSES.

formed on the retinas of the two eyes produce but a single sensation, and create the impression of solidity. It is well known that by this means we habitually estimate the relative positions of objects which are not very far away; with respect to distant objects little stereoscopic effect is produced, since the distance between the two eyes subtends but a small angle at a distant point, and therefore the images impressed on the two retinas are practically indistinguishable.

In using the stereo-telescope (Fig. 6), the stereoscopic effect produced is similar to that which would be observed by our unaided eyes if these were as far apart as the two outer ends of the telescope, *i.e.* from 0·5 to 1·5 meter, according to the size of the instrument. Consequently, when fairly distant objects are viewed by the aid of the stereo-telescope, the nearer ones appear to "stand out" from those farther away, much as objects close to the observer do in ordinary vision.

FIG. 5.—THE ZEISS FIELD GLASSES.

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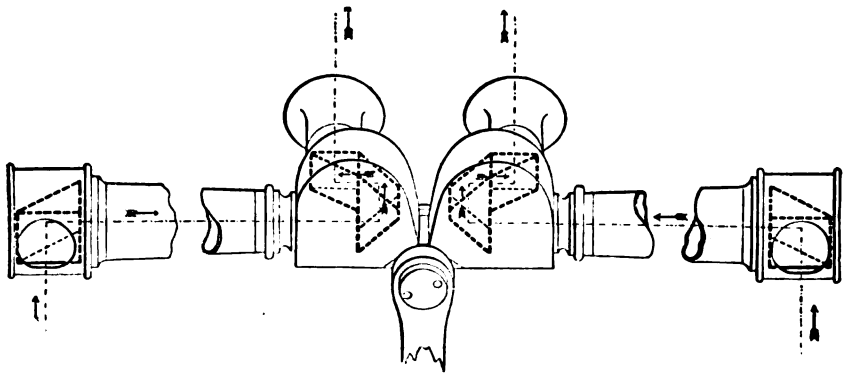

FIG. 6.—ZEISS STEREO-TELESCOPE.

As just explained, distant objects when viewed by the aid of the stereo-telescope stand out in bold relief; this suggests that a stereo-telescope could be used to find the distances from the observer to fairly remote objects. This result has been achieved in the Zeiss stereoscopic range-finder. The principle of this instrument may be explained as follows: Let us suppose that a row of equidistant posts (shown in the plan in the upper part of Fig. 8) stretches away straight in front of the observer; then if R and L indicate the respective positions of the right

Stereoscopic Range-finder

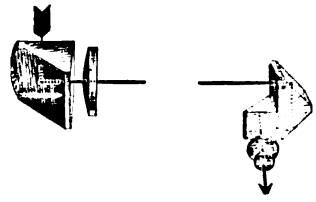

FIG. 7.—OPTICAL ARRANGEMENT, STEREO-TELESCOPE.

and left eyes of the observer, lines drawn from the various posts to R and L will coincide with the rays by which these posts are seen. Let A B be the trace of a vertical plane in front of the observer, and let the points in which the rays cut this plane be noted; then if perspective views of the posts (similar to those shown in the lower part of Fig. 8) are drawn in their proper positions in the plane A B, and are stereoscopically viewed, the appearance presented will agree exactly with that produced by the actual posts when viewed with both eyes.

Now let us suppose that the same row of posts (the distance between two adjacent posts being, say, one hundred yards) are viewed with the stereo-telescope (Fig. 6). Separate real images are formed in front of the two eye-pieces, and on viewing these images through the eye-pieces an enhanced stereoscopic effect is obtained, owing to the considerable distance between the two receiving apertures of the telescope. If the images viewed through the eye-pieces were photographed, and the photographs were placed in front of their respective eye-pieces, then on looking into the telescope the impression gained would be that of a row of posts stretching away from the observer, in enhanced stereoscopic relief. If we now direct the telescope toward any distant object, this also will be seen in stereoscopic relief, and it is easy to determine which two of the posts it lies between; hence, the distance of the object can be determined at a glance with considerable accuracy. In practice, two engraved and numbered scales are placed in

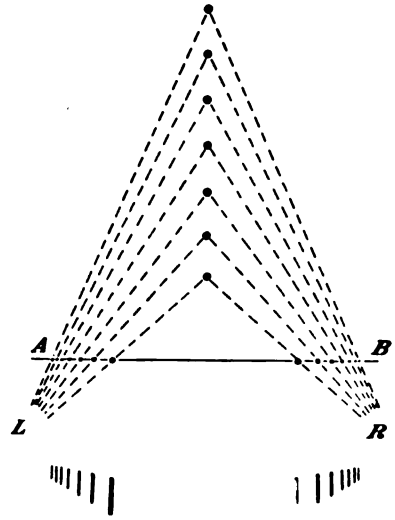

FIG. 8.—TO EXPLAIN PRINCIPLE OF STEREOSCOPIC RANGE-FINDER.

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the eyepieces, in place of the photographic representations mentioned above; but it is plain that if the various divisions coincide with the positions occupied by images of the equidistant posts, then we obtain a scale which, when seen in stereoscopic relief, gives us the means of determining the distances of remote objects. When the distance between the receiving apertures of the telescope is 1·5 meters, and the magnifying power of the instrument is 23, the error in determining a distance of about 1,000 meters does not exceed 4 or 5 meters; when the distance to be determined is about 3,000 meters, the error amounts to about 40 meters.

Tantalum

SEVERAL years ago Messrs. Siemens and Halske started an investigation with the aim of finding some substance which could be profitably used in place of carbon in the construction of electric incandescent lamps. The task of carrying out the preliminary chemical and physical research was entrusted to Dr. W. von Bolton, who has examined a great number of substances with exemplary care and patience, and has succeeded in finding one which may ultimately prove a successful rival to carbon. It is well known that the proportion of white light emitted, for a given expenditure of energy used in heating a substance, increases progressively with the temperature to which the substance is raised; hence the problem attacked by Dr. Bolton consisted in finding a substance of very high melting point which could be formed into thin filaments suitable for the manufacture of incandescent lamps. The higher the resistivity of the substance, the greater would naturally be the chance of success; for a substance of low resistivity would need to be formed into a filament of such great length that it would be difficult to arrange it within a bulb of reasonable dimensions.

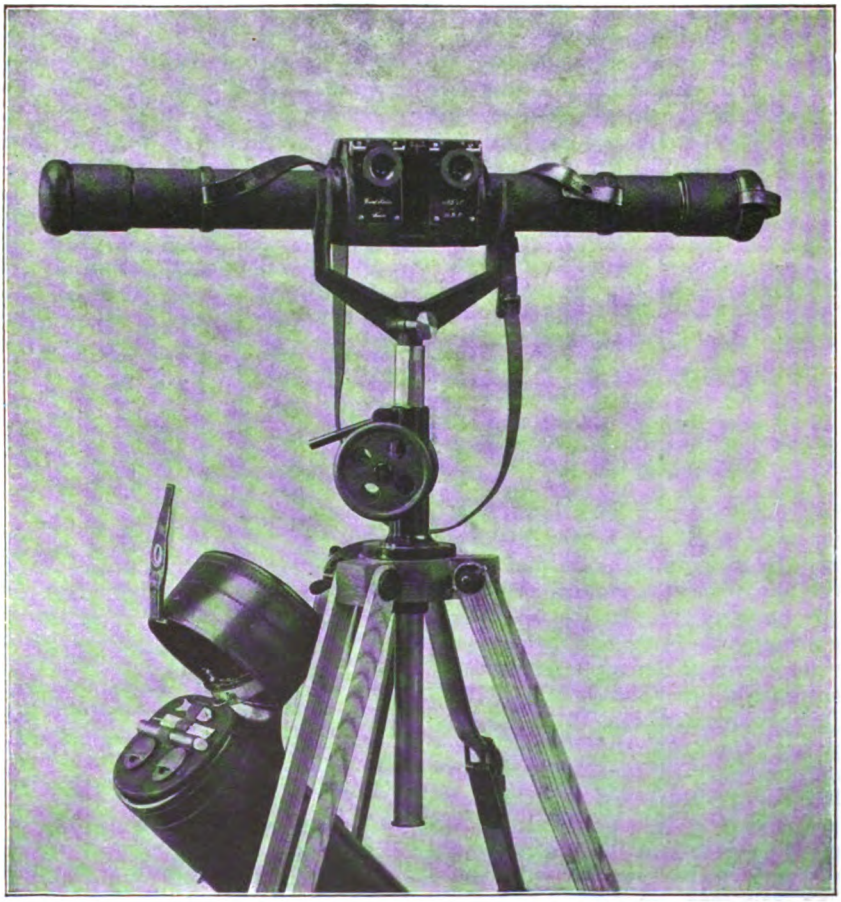

FIG. 9.—STEREOSCOPIC RANGE-FINDER, MOUNTED READY FOR USE.

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Dr. Bolton first reduced vanadic pentoxide electrolytically, but found that the melting point of vanadium was too low for the purpose in view. In the same group as vanadium are the metals niobium and tantalum, the atomic weight of niobium being twice, and that of tantalum four times the atomic weight of vanadium. Experiments carried out with regard to niobium showed that its melting point, though higher than that of vanadium, is still too low for this metal to be used in connection with electric glow lamps; consequently tantalum was next tried, in the hope that its greater atomic weight would be associated with a higher melting point. Potassium tantalo-fluoride was reduced in the manner prescribed by Berzelius and Rose; it was found that the finely divided tantalum, if melted in a vacuum, parts with its occluded gases, and can be rolled into strips or filaments. The properties of tantalum are very interesting. This metal is not attacked by boiling hydrochloric acid, aqua regia, nitric acid, or sulphuric acid; it is also indifferent to alkaline solutions. It is attacked solely by hydrofluoric acid. Thin filaments, when ignited, burn with a low intensity and no visible flame. At a low red heat it absorbs hydrogen as well as nitrogen, and forms with these a brittle substance of metallic appearance. It also forms a number of carbides, all of which are very brittle. It appears that the substance obtained by Moissan, and supposed by that investigator to have been tantalum, was in reality one of these carbides. Pure tantalum has a density of 16·8 grams per cubic centimeter; its atomic weight is 183, and its specific heat is 0·0365, so that the "atomic heat" is 6·64, which is in agreement with Dulong and Petit's law. Tantalum is somewhat darker than platinum, and has a hardness about equal to that of mild steel; it, however, is stronger than steel, its tensile strength having the exceptionally high value of 95 kilograms per square millimeter, or 60 British tons per square inch: according to Kohlrausch the tensile strength of steel lies between 45 and 50 tons per square inch. The electrical resistivity of tantalum is equal to 16·5 microhms per centimeter cube, or ten times that of copper; and between 0° and 100° C. its temperature coefficient (increase in resistance per degree rise of temperature for each ohm at 0°) is equal to 0·003. When a tantalum filament is used in an electric glow lamp, its temperature being such that 1·5 watts produce 1 candle-power, the resistivity rises to 83 microhms per centimeter cube. The coefficient of thermal expansion of tantalum is equal to $7·9 \times 10^{-6}$, while that of platinum is $9·0 \times 10^{-6}$.

The Tantalum Lamp

THE task of making a commercial lamp from tantalum was entrusted to Dr. O. Feurlein: the intrinsic difficulty of this task can scarcely be overrated. A 110 volt lamp producing a light equivalent to 25 to 32 candle-power must have a filament rather more than 2 feet long, if the diameter of the filament is equal to 0·05 millimeters, the smallest diameter which could be used with any chance of success. The way in which this difficult problem has been solved can be seen from Fig. 10, which represents a 110 volt, 25 candle-power lamp. The filament is 65 centimeters in length, and is wound in a zigzag course between a number of metallic arms fused into a central glass support. The mass of a filament is 0·022 grams, so that 23,000 lamps would together contain about a pound of tantalum. This lamp can be used so that a power expenditure amounting to 1·5 watts produces 1 candle-power; under these conditions a lamp lasts 400 to 600 hours in actual use before the efficiency diminishes 20 per cent. Some specimens have proved to have a useful life of as much as 1,200 hours; most last as long as 800 to 1,000 hours before becoming useless.

As in the carbon filament lamp, the efficiency of the tantalum lamp increases during the first few hours by about 15 to 20 per cent.; during this interval the resistivity of the filament diminishes, a larger current passes, and a higher temperature is acquired, so that the power consumption drops to 1·3 or 1·4 watts per candle-power. After this the efficiency slowly diminishes, so that after 1,000 hours the power consumption amounts to 2·1 or 2·2 watts per candle. An old lamp can be easily distinguished from a new one, since the filament acquires a peculiar glistening appearance with age.

Advantages of the Tantalum Lamp

THE tantalum lamp possesses the very obvious advantage over the carbon filament lamp, that whereas the latter cannot be safely run with a smaller power expenditure than about 3 watts per candle-power, the tantalum lamp can be run at 1·5 watts per candle-power. It has another important advantage which must not be overlooked. The resistivity of carbon decreases with a rise of temperature, so that a temporary increase of voltage causes the resistance of

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the carbon filament lamp to decrease, with the result that the power expended increases much more quickly than the voltage. Consequently a comparatively small fluctuation in the voltage is sufficient to "burn out" a carbon filament glow lamp; if it were not for this instability of the carbon filament, fluctuations in the supply voltage, much larger than those which are now considered prohibitively high, would be quite permissible; and thousands of pounds which must now be expended in laying down low resistance mains would be saved. The tantalum filament, owing to its positive temperature coefficient, is stable over very wide fluctuations of voltage: thus a 110 volt, 25 candle power lamp will not be destroyed, even by raising the voltage to 260 or 300 volts, provided the rate of increase is fairly gradual.

As compared with the Nernst lamp, the tantalum lamp has the advantage that the filament glows directly on the circuit being closed. As compared with the osmium lamp, the chief advantage of the tantalum filament is that it is much stronger than the filament of osmium, so that it is possible to make lamps for fairly high voltages. Hence it appears that the tantalum lamp has a future of great promise before it. It can hardly be said at present to have entirely passed the experimental stage, but we cannot but look forward with hope to its future success.

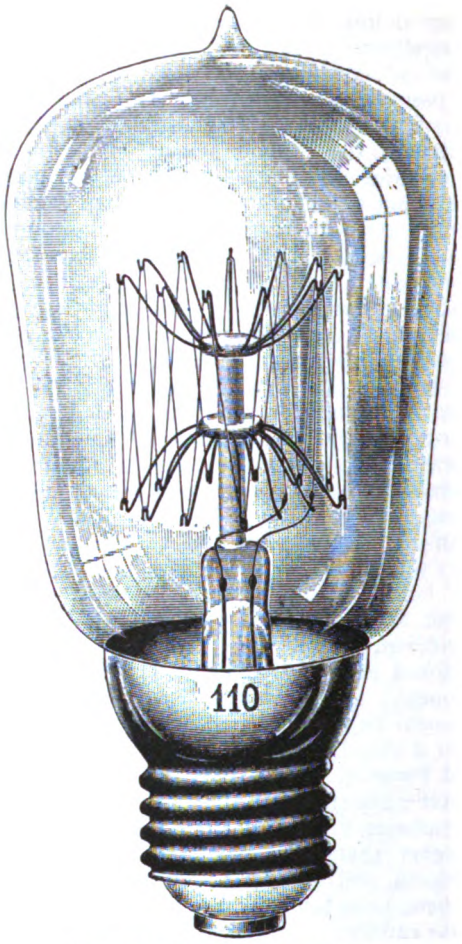

FIG. 10.—THE TANTALUM LAMP.

Water Softening

THE process of water softening was described in the January number of TECHNICS, pp. 5 to 7, where reference was made to one of the commercial forms of water softeners. Another commercial process of the greatest value is that known as the Archbutt-Deeley process, plant for which is made by Messrs. Mather and Platt, Ltd. In this process large quantities of water are softened at a time in a tank, or a number of tanks, which also serve to store the softened water ready for use. The nature of this plant is shown diagrammatically in Fig. 12, which represents a double tank plant. The hard water is admitted at H, near the bottom of the tank, until the level of the water reaches a gauge mark. Meanwhile, the chemicals used in softening the water are weighed out, and boiled up in the chemical tank C, by means of live steam. Some waters require also the addition of a little aluminoferric: this is conveniently prepared in the form of a standard solution, of which a measured volume is added to the hard water after the other chemicals have been mixed with it.

Adding the Softening Re-agents

THE method by which the softening re-agents are added to the hard water is as follows. Steam is blown downwards through the blower B; and a tap having been opened, the water in the tank is drawn upwards through the rose R, and finally forced downwards through the vertical pipe V, and then discharged into the tank through perforations in the upper horizontal pipes P. By opening another tap, the chemical solution is drawn from the tank C and mixed with the hard water as it descends the vertical pipe V. In a very short time the whole of the water in the tank will have been mixed with the softening re-agents, and the calcium and magnesium salts will have been separated according to the equation given in the January number of TECHNICS. The precipitate is, however, in a very fine state of division, with the result that it would naturally settle very

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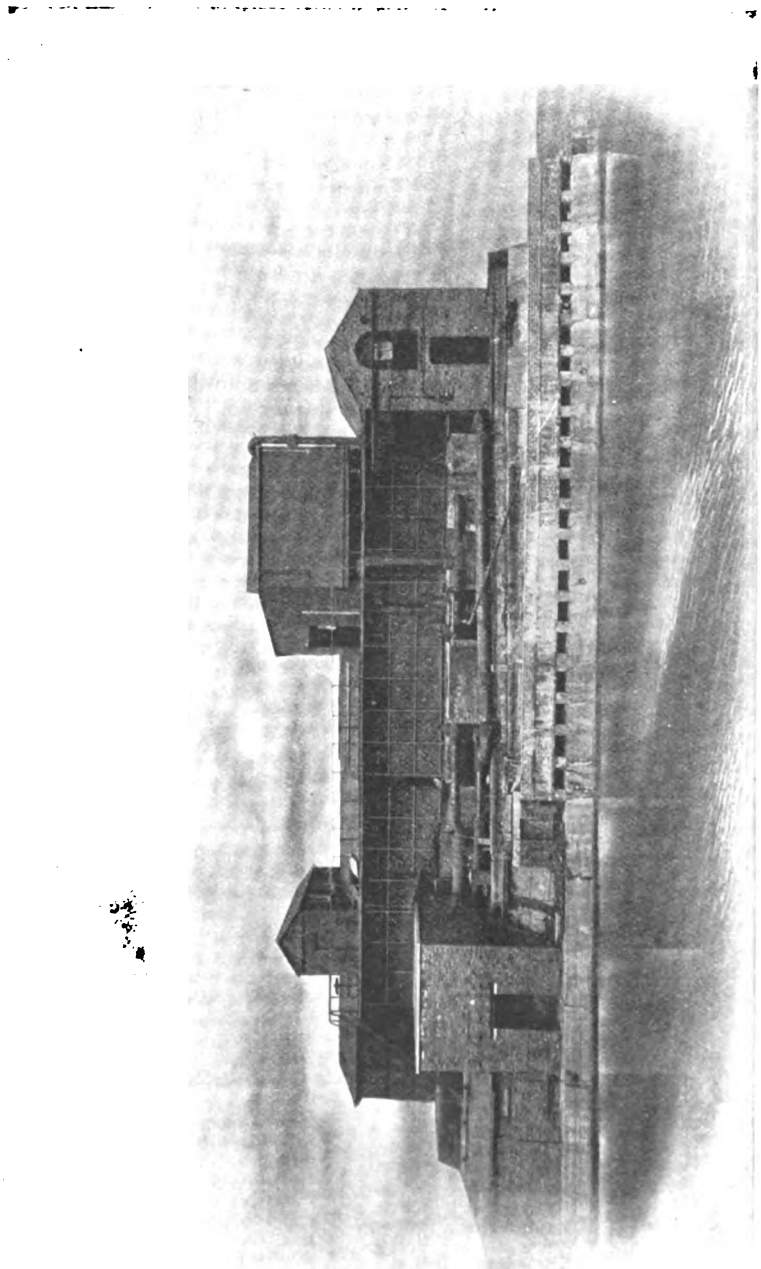

FIG. 11.—ARCHBUTT-DEELEY WATER-SOFTENING PLANT, ERECTED AT THE WILLESDEN WORKS OF THE METROPOLITAN ELECTRIC SUPPLY COMPANY, BY MESSRS. MATHER & PLATT, LTD.

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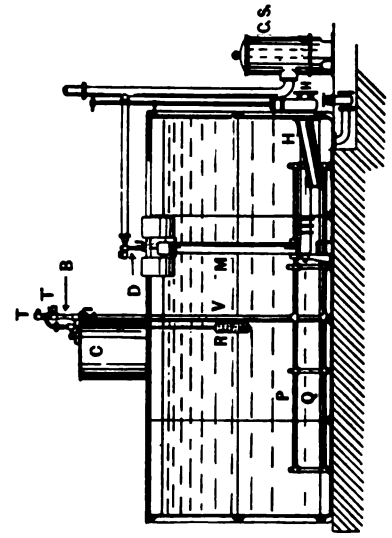
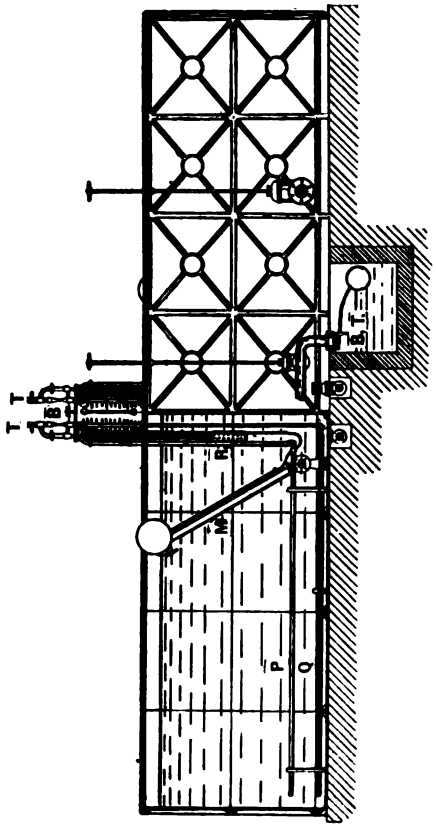
slowly; it has been found, however, that if the precipitate from a previous operation is mixed with the contents of the tank, the whole of the new precipitate will be carried down in a very short time. To effect this result, the air tap T is opened, and the blower draws in air, which, by turning a cock provided for that purpose, is forced downwards and discharged from perforations on the lower side of the horizontal pipes Q. The air is thus blown through the precipitate from previous operations, and as this subsequently sinks through the liquid, it carries the new precipitate down with it. About an hour after the steam has been turned off, it is found that the whole of the precipitate has settled to the bottom of the tank, leaving the softened water perfectly clear and bright.





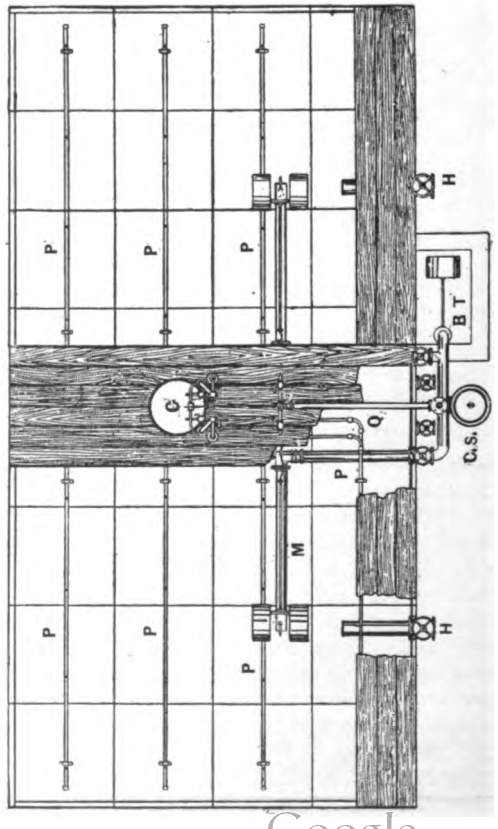


FIG. 12.—WATER-SOFTENING PLANT.

IT is sometimes advisable to finally convert all the salts remaining in solution in the water into the form of carbonates. This **Carbonating** is effected as follows. The softened water leaves the tank near the upper surface of the water by way of the discharge pipe M, which is hinged at its lower extremity, its upper end being kept near the surface of the water by the aid of floats; it is discharged by way of the ball tap BT. Fuel gas from the

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coke stove CS is forced into the water just in front of the orifice of the pipe M, by means of the steam blower D, and is carried down by the descending current of water, and discharged with this at the ball tap BT. The quantity of carbonic acid required is only just enough to convert the slight excess of alkali used in softening into the bicarbonate. No injurious effects are produced by the sulphuric acid in the fuel gases due to the presence of sulphur in the coke, since the quantity of sulphuric acid formed is at most very small. Experience proves that for boilers, carbonating is not always necessary; and where it is necessary, it need only occasionally be performed, in order to prevent any trouble from deposit in the pipes.

Winding of Rivers

A NOTE on the winding of rivers, which appeared in the January number of TECHNICS (Vol. II., p. 4), has called forth some criticisms from Mr. T. S. Ellis, who has devoted much attention to the subject. Mr. Ellis accounts for the winding of rivers in the following

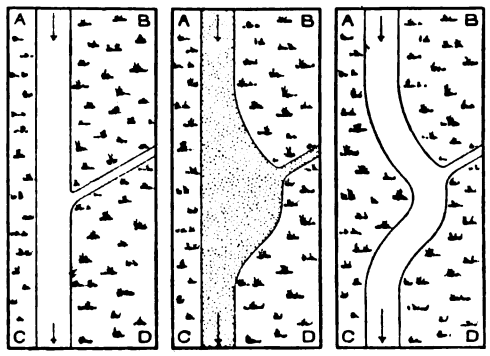

FIG. 13.—TO ILLUSTRATE MR. ELLIS'S THEORY OF RIVER CURVES.

manner:—Let ABCD (Fig. 13, *a*) represent an alluvial area traversed by a straight river receiving a tributary. Mr. Ellis considers that in flood time the tributary will wash away the banks where it enters; at every successive flood time the whole bed of the river and the adjoining area of land will be covered with water, and from this water suspended matter will fall and form a deposit. Mr. Ellis states that the quantity of deposit will be greater in the channel of the river than elsewhere; he accounts for this on the supposition that the water at the bottom of the channel will be stagnant, owing to the greater pressure to which it is subjected. On this point we cannot agree with Mr. Ellis, since the velocity of the water does not depend on the pressure to which it is subjected: it appears more probable that the greater deposit in the river bed is due to the greater amount of water which flows along this course. Be this as it may, Mr. Ellis assumes the condition of the river, after the subsidence of the flood, to resemble that represented in Fig. 13, *b*, where the dotted area represents deposited mud. The tributary, however, will keep open a passage for its waters, so that the final condition of the river is that represented in Fig. 13, *c*. There appears to be no reason why the causes mentioned should not be operative in producing winds in a river, but we cannot agree with Mr. Ellis in assuming that this is the only cause. The action described in the January number of TECHNICS must certainly occur at every point in a river bed where there is any initial tendency to winding; it could not make a perfectly straight river wind, but any accidental circumstance which produced an incipient bend would render the straight course of the river unstable, and the bend would continually become more pronounced. This action can be watched in progress in the mud banks at the mouth of the Mersey: owing to the soft nature of the mud, the rivulets flowing through it rapidly cut away the mud on their concave margins and deposit it on their convex margins. This action will, of course, be most noticeable in cases where the flow of water is rapid, and the banks of the river or rivulet are soft and easily disintegrated.

Cotton Cultivation in British Guiana

THERE has been a revival in the cultivation of cotton throughout British Guiana, and success has been general, owing to the intensity of the heat. Fig. 14 shows matured cotton in the pods ready for picking, from the plantation of George Farmer and Co., No. 1 Canal, British Guiana. Immense trouble has been given by the "red bug," which in the States is called the "cotton stainer." George Farmer and Co. have been successful in discovering an insecticide which effectually destroys these and all other insect pests which are so inimical to the cotton-growing industry.

Before one of the principals left the Colony he gathered a large bunch of growing and developing cotton, not knowing that it was infested with red bugs. The bunch was packed away in a case and brought to England: after a month the case was opened, and, on examining the cotton, it

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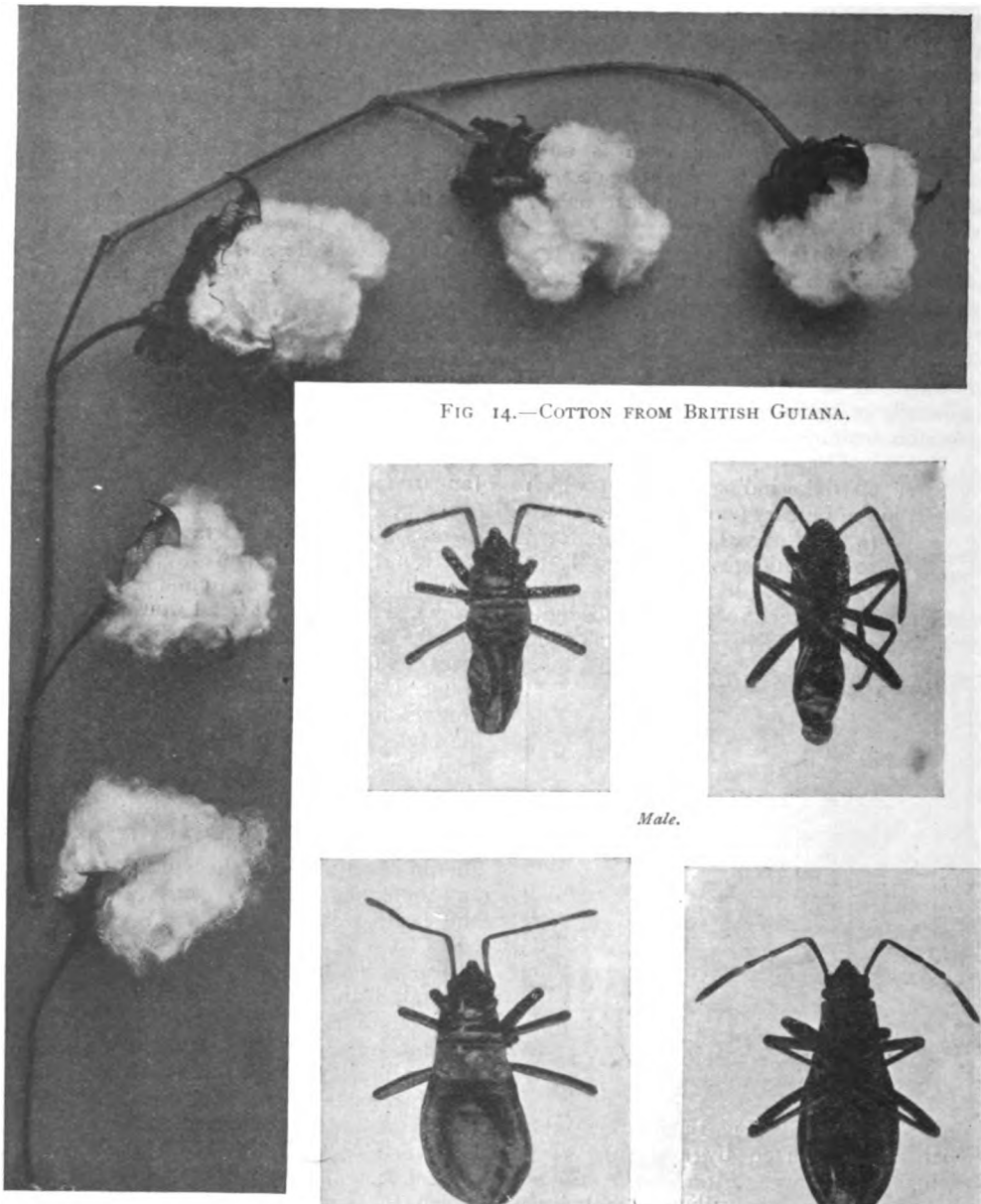
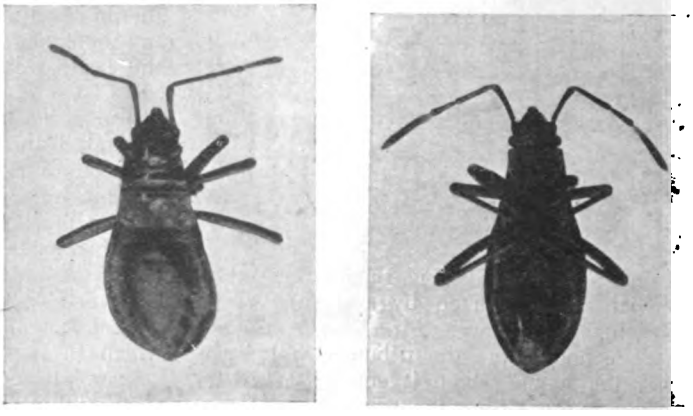


FIG 14.—COTTON FROM BRITISH GUIANA.

Male.



Female.

FIG. 15.—BACK AND FRONT VIEWS OF THE "RED BUG," MALE AND FEMALE.
Magnified about 4 diameters.

was found to contain a number of the red bugs in an inanimate condition. Not without surprise, however, it was observed that the bugs were only torpid: after being warmed for a few moments they were as lively as if back in the intense heat of the tropics. A number of these bugs were brought to the office of TECHNICS on a cold winter morning, and were submitted to our examination. On warming the cardboard box in which they were contained before a brisk fire, the bugs recovered their vitality, but quickly became torpid again when removed to another part of the room. Subsequent warmings failed to

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rouse them, so that it appears that they are only capable of recovering from their torpidity for a limited number of times. This appears strange, since the bugs came from the banks of the Essequibo river, where the days are excessively hot and the nights are so cold that there can be no doubt that the bugs periodically become torpid. Perhaps, however, it is necessary for the bugs to acquire some nutriment after being aroused, and before they once more sink into a torpid condition.

These bugs secrete themselves round the pod of the cotton. Immediately the pod breaks they enter the mass of ripe fibres, which they devour. If care is not exercised by the pickers when they collect the cotton, red bugs may be included, in which case the value of the cotton deteriorates. If the bugs are crushed, the red fluid which exudes from them destroys the whole of the cotton, so that a sample that would otherwise be worth 1*s.* 6*d.* per pound becomes almost worthless. Fig. 15 shows dorsal and ventral views of these red bugs, male and female insects being represented. These illustrations have been reproduced from photographs of the bugs left at the office of TECHNICS, as previously mentioned.

Siloxicon and Silicon

SOME notes upon the discovery and manufacture of siloxicon, the new electric furnace product, were given in our November issue (see p. 438). It was there stated that siloxicon is a very refractory compound of silicon, carbon and oxygen, and that it is produced by heating ground coke, sand and sawdust to a temperature of 2600°C. in the electric furnace. The material, when ground, is employed for making crucibles, and for lining furnaces intended for high temperature reactions, and a company has now been formed in the United States to undertake the manufacture of bricks, crucibles, retorts, and furnace linings of this product. A works at Niagara Falls, and an office in New York, are about to be started in connection with this project. As regards the element metallic silicon, this has been produced on a large scale at Niagara Falls by aid of the electric furnace. F. J. Tone, who has produced half a ton of the metal in this way is, however, handicapped by the fact that there is no demand at present for this new addition to the list of metals produced on a commercial scale; and until some profitable application has been found for it, the manufacture is unlikely to develop. Silicon has a very high degree of affinity for oxygen, and in the forms of silicon, copper and ferro-silicon it has already attained a large sale for metallurgical purposes, these alloys being added to copper and iron respectively at the moment of casting, in order to remove both the free and combined oxygen, and improve the density and character of the castings. According to Ostwald, the heat of formation of all the silicon compounds is still very uncertain, but the fact that this element can rob both iron and copper of their oxygen when introduced into molten metal containing oxides of these metals, proves that the heat of formation of silicon oxide must be exceptionally large. Silica and alumina are, in fact, the two most commonly occurring oxides in the earth's crust, the former representing over 55 per cent. of the total weight; and, therefore, one may assume that these two elements have the greatest affinity for oxygen of all the metals found near the earth's surface. Should any useful and profitable application be found for metallic silicon, the electric furnace method of production is therefore likely to extend.

Helium in Pitchblende

No compound of the element helium has yet been discovered, but the large proportion of this gas that is contained in pitchblende has suggested the possibility that some compound of the gas might be present in the mineral. This problem has recently been attacked by Mr. R. J. Moss, whose observations are described in the Transactions of the Royal Society of Dublin. A quantity of the mineral, which had been dried over sulphuric acid *in vacuo*, was ground by means of a special apparatus in an exhausted space, so that the gas liberated by the grinding could be collected. The gas liberated from 73 grams of the mineral by two grindings amounted only to 0·186 c.c. of which about one-half consisted of helium. When 15 grams were decomposed by fusion with potassium hydrogen sulphate, no less than 74 c.c. of gas were liberated, consisting mainly of carbon dioxide, but containing also 1·56 c.c. of helium. The proportion of helium liberated by grinding and by chemical action is very similar to the proportion of carbon dioxide liberated from calcspar by similar treatment, but the author nevertheless concludes that the helium in pitchblende is not combined, but included in minute cavities which are not broken by the coarse grinding to which the mineral was submitted.

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THE MECHANICS OF HEAVY ELECTRIC TRACTION.

PART IV.—THE TRACTIVE FORCE, POWER AND ENERGY AT AXLES.

By H. F. PARSHALL and H. M. HOBART.

UP to this point the relations between speed, distance and time have alone been considered. The corresponding tractive force must next be discussed.

During acceleration at a constant rate on a level, the tractive force is made up of two components, the one constant and a function of the rate of acceleration, and the other a variable component and a function of the speed from instant to instant. During operation on the level at constant speed, the tractive force is also constant and is a function of the speed. The tractive force required for acceleration, and corresponding to various rates of acceleration, has already been given in Table III., on p. 432 of Vol. II. of TECHNICS, November, 1904. To these must be added the variable tractive force from instant to instant, required for overcoming the tractive resistance as the speed increases. The percentage difference which this introduces is a function of the rate of acceleration and of the weight of the train. In Figs. 33A, 33B, and 33C are given curves showing, for 50-ton, 200-ton and 800-ton trains, the tractive force required per ton weight of train, to maintain various rates of acceleration during the accelerating period. It is seen that throughout this wide range of train weights (*i.e.*, from 50-ton to 800-ton trains), the variation with the weight is not great, and in order to simplify the calculations, the tractive force per ton weight of train corresponding to a 200-ton train will be taken, irrespective of the weight of the train.

Thus the curves of Figs. 34A, 34B, 34C and 34D, which really refer to the tractive force per ton weight of train for a 200-ton train, will be employed for all train weights, and it may be kept in mind that this gives somewhat too liberal values for long trains and somewhat too low values for short trains.

Let us take the case of a train operating with one stop per mile at an average speed of thirty miles per hour between stops. Assuming constant rates of acceleration and retardation, and a uniform rate of speed from the completion of acceleration to the commencement of retardation, the speed-time curves for accelerating rates of 1·0, 1·4, 1·8 and 2·2 miles per hour per second will be those already given in the curves of Fig. 16A and in the left-hand curves of Fig. 17.* These curves are repeated in the upper row of Fig. 35. The corresponding tractive force-time curves are given in the second row, the constant speed figures relating to a 200-ton train,† and the rate of expenditure of energy at the axle, in foot-pounds per second per ton weight of train, is given in the third row. As a kilowatt equals 737 foot-pounds per second, the energy expended in kilowatts at the axle per ton weight of train moved is readily deduced, and is given in the fourth row of curves. The fifth row of curves shows the total watt-hours at the axle per ton weight of train which, at any given time from the start, have been required. Hence the value at the point of cutting off the current represents the watt-hours at the axle per ton-mile for the entire run from start to stop.

This, for the different rates of acceleration, is as follows:—

TABLE V.

CONSUMPTION OF ENERGY AT AXLES IN WATT-HOURS PER TON-MILE. ONE STOP PER MILE.

Rate of Acceleration in miles per hour per second.	Watt-hours at the axles per ton-mile, for a 200-ton train, operated at a schedule speed of 30 miles per hour between one-mile stops.
1·00	117
1·40	57
1·80	50
2·20	47

The results in Table V. are plotted in the curve of Fig. 36. It is evident that, so far as relates to obtaining a low rate of expenditure of energy at the axles in watt-hours per ton-mile, a high rate of acceleration is desirable. It will be seen later, however, that this may entail an unduly heavy equipment and other disadvantages.

* TECHNICS, Vol. II., No. 11, November, pp. 428–429.

† A representative 200-ton train will be assumed in much of the following discussion. Rough modifications of the results will generally give a basis for sufficiently accurate values for lighter and heavier trains.

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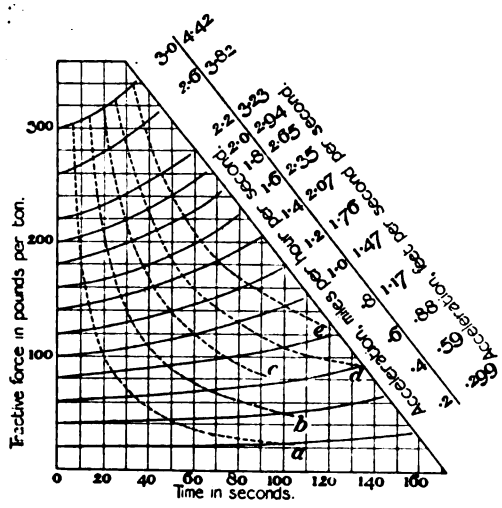


A.—50-*ton Train.*

Speed.	Miles per hour.	Feet per second.
a	20	29·4
b	40	59
c	60	88·5
d	80	118
e	100	147

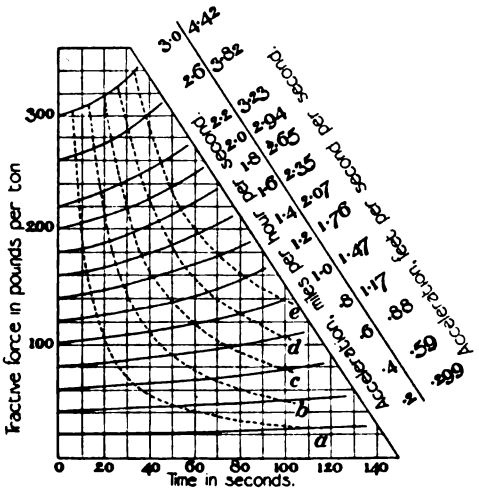
An interesting point to note is that the maximum instantaneous load at the axles required for this average speed of thirty miles per hour between stops and one stop per mile, first decreases with increasing acceleration, and after passing through a minimum at a rate of acceleration of about 1·3 miles per hour per second, again increases with higher accelerations. This may be seen from the third and fourth rows of diagrams in Fig. 35, but is more clearly brought out in the curve of Fig. 37.

The average power at the axles in kilowatts per ton weight of train, for a 200-ton train operating at an average speed of thirty miles per hour between stops, and with one stop per mile for these four rates of acceleration, is readily derived from the values in Table V. and is given in Table VI.

TABLE VI.

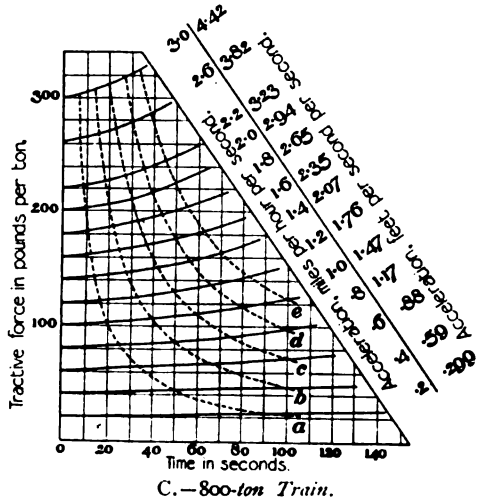
AVERAGE POWER AT AXLES IN KILOWATTS PER TON. ONE STOP PER MILE.

Rate of Acceleration in miles per hour per second.	Average Power at Axle.
1·0	3·50 kilowatts
1·4	1·71 ,,
1·8	1·50 ,,
2·2	1·41 ,,



B.—200-*ton Train.*

Speed.	Miles per hour.	Feet per second.
a	20	29·4
b	40	59
c	60	88·5
d	80	118
e	100	147



C.—800-*ton Train.*

Speed.	Miles per hour.	Feet per second.
a	20	29·4
b	40	59
c	60	88·5
d	80	118
e	100	147

FIG. 33.—CHART SHOWING TRACTIVE FORCE, WITH VARIOUS ACCELERATING RATES, FOR TRAINS OF DIFFERENT WEIGHTS.

Dotted curves relate to speed.

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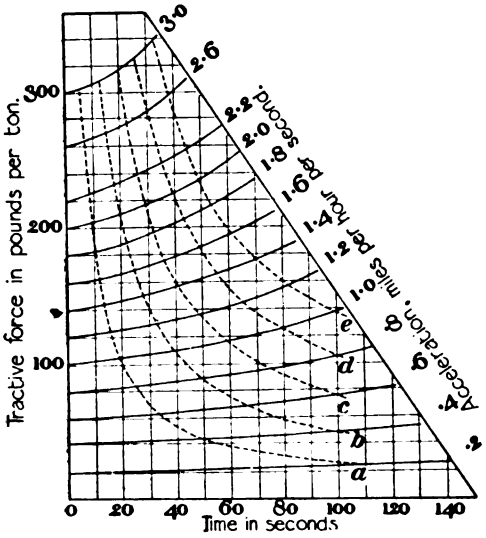
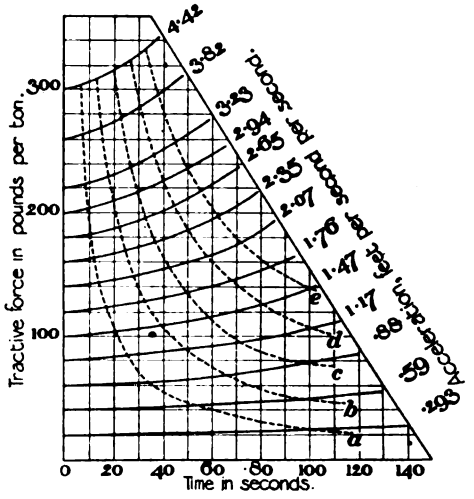


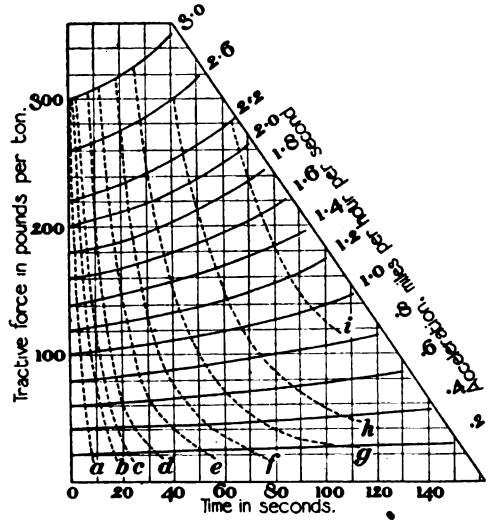
A.—*Dotted curves relate to speed.*

Speed.	Miles per hour.	Feet per second.
a	20	29·4
b	40	59
c	60	88·5
d	80	118
e	100	147



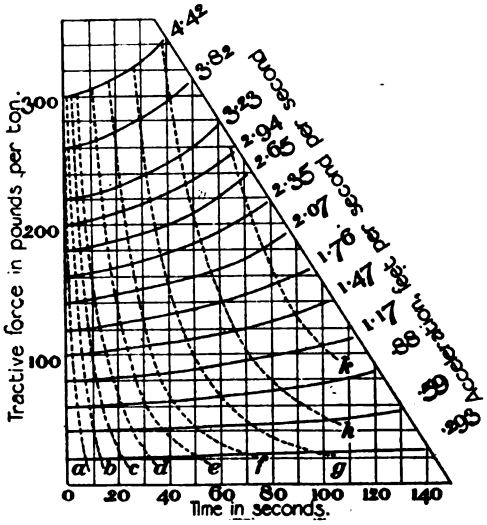
C.—*Dotted curves relate to speed.*

Speed in feet per second.	
a	30
b	60
c	90
d	120
e	150



B.—*Dotted curves relate to distance.*

	Distance in miles.	Distance in feet.
a	0·005	26·4
b	0·01	52·8
c	0·02	105·6
d	0·04	211·2
e	0·08	422·4
f	0·16	844·8
g	0·32	1689·6
h	0·64	3379·2
i	1·28	6758·4



D.—*Dotted curves relate to distance.*

	Distance in feet.
a	25
b	50
c	100
d	200
e	400
f	800
g	1600
h	3200
k	6400

FIG. 34.—CHART SHOWING TRACTIVE FORCE, WITH VARIOUS ACCELERATING RATES, FOR A 200-TON TRAIN. (*Average for all Trains.*)

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The results in Table VI. are plotted in Fig. 38, and this also is in favour of a high accelerating rate.

For the same schedule speed of thirty miles per hour, but with but one stop per two miles, the calculations will be carried out tabularly instead of by diagrams. The steps may be readily followed from Table VII.

As the purpose of these calculations is restricted to setting forth limitations and imparting ideas of the general magnitude of the quantities involved, it would be out of place to employ any close degree of accuracy; thus but three, and often only two, significant figures are employed.

In Table VII., by expressions such as "energy expended at the axles" is meant the propelling energy alone. The braking energy subsequently expended in virtue of the stored-up energy of the train, is, for low rates of acceleration, often a very large percentage of the total energy expended at the axles in propelling the train. A considerable portion of this may be recovered by "regenerative control" methods. The amounts involved are shown in Table VIII.

Item XIII. of Table VIII. gives the percentage of *recoverable* energy; this only represents the *recovered* energy on the basis of 100 per cent. efficiency of recovery. Of course, the recovery will be at far less than 100 per cent. efficiency, for the motors must act as dynamos with very variable speed and load, and there will be external waste in controlling the rate of regenerative braking. Assuming that the energy required from the trolley or third rail averages 1·33 times the energy expended at the axles in propelling the train, and that the stored energy is recovered at 66·7 per cent. efficiency, then the percentages of recovered energy for the case analysed in Tables VII. and VIII. are as set forth in Table IX.

TABLE IX.

Assumptions are :—
Energy input = 1·33 × energy at axles.*
Mean efficiency of recovery by regenerative braking = 66·7%.

Rate of Acceleration in miles per hour per second.	Energy input to train in watt-hours per ton-mile. (1·33 × XII. of Table VIII.)	Energy recovered by regenerative braking in watt-hours per ton-mile. (0·667 of XI. of Table VIII.)	Percentage of energy recovered to energy input to train.
0·50	79	27	34%
0·60	53	15·3	29%
1·00	43	10·7	25%
1·40	40	10·0	25%
1·80	38	9·4	25%
2·20	36	8·7	24%

Thus by means of reconverting to electrical energy for return to the line, we may, in the above case, recover some 30 per cent. of the energy input to the train. Of course, this percentage varies greatly, depending chiefly upon the frequency of stops and the schedule speed between stops. In the case of tramway

* This value will vary considerably with the type of equipment, the rate of acceleration, the schedule speed, and the number of stops per mile, and is only taken as a rough value for illustrative purposes.

TABLE VIII.

Rate of acceleration in miles per hour per second	I.	0·50	0·60	1·00	1·40	1·80	2·20
Maximum speed, *i.e.*, speed at completion of acceleration, in miles per hour	II.	60	43	35	33	32	31
Stored up energy of motion per ton weight of train at above speed — In foot-pounds ($34·2 \times IV.^2$ of Table VII.)	III.	265000	136000	91000	30600	75500	71000
Stored up energy of motion per ton weight of train at above speed — In watt-hours (III. ÷ 2650)	IV.	100	51	34	30	28·5	27
Non-recoverable energy at axles in watt-hours per ton weight of train, *i.e.*, energy wasted in inevitable friction — For accelerating interval (XVII. of Table VII. minus IV. of Table VIII.)	V.	18	5	2	1·1	0·9	0·6
Non-recoverable energy at axles in watt-hours per ton weight of train, *i.e.*, energy wasted in inevitable friction — For constant speed interval (XVIII. of Table VII.)	VI.	0	25	28	28	28	28
Non-recoverable energy at axles in watt-hours per ton weight of train, *i.e.*, energy wasted in inevitable friction — For retarding interval (same as V.)	VII.	18	5	2	1·1	0·9	0·6
Non-recoverable energy at axles in watt-hours per ton weight of train, *i.e.*, energy wasted in inevitable friction — Total of non-recoverable energy for 2-mile run from start to stop (V. + VI. + VII.)	VIII.	36	35	32	30	30	29
Total non-recoverable energy in watt-hours per ton-mile (VIII. ÷ 2)	IX.	18	17	16	15	15	14
Recoverable energy in watt-hours per ton (IV − VII.)	X.	82	46	32	29	27·6	26·4
Recoverable energy in watt-hours per ton-mile (X. ÷ 2)	XI.	41	23	16	15	14	13
Watt-hours expended at axles per ton-mile (IX. + XI.)	XII.	59	40	32	30	29	27
Recoverable energy per ton-mile in percentage of energy expended at axles, *i.e.* (XI. in per cent. of XII.)	XIII.	70%	58%	50%	50%	49%	48%

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Table VII.

For a run of 2 miles between stops, at an average speed of 30 miles per hour, this table sets forth the calculations of the tractive force (T.F.) power and energy at the axles per ton weight of train for a 200-ton train at various rates of acceleration, the braking giving a rate of retardation equal to the rate of acceleration.

Rate of acceleration	Miles per hour per second	I.	0·50	0·60	1·00	1 40	1·80	2·20
	Feet per second per second	II.	0·74	0·83	1·47	2·06	2·64	3·23
Speed at completion of acceleration, *i.e.*, maximum speed (from Fig. 27)	Miles per hour	III.	60	43	35	33	32	31
	Feet per second	IV.	88	63	51·5	48·6	47·0	45·5
Time, in seconds, occupied by acceleration (III. ÷ I.)		V.	120	71·8	35·0	23·6	17·8	14·1
Time, in seconds, occupied by entire 2-mile run between stops		VI.	240	240	240	240	240	240
Duration, in seconds, of operation at maximum speed (VI. − 2 × V.)		VII.	—	96	170	193	204	212
Tractive force at completion of acceleration, in lbs. per ton (from Fig. 34A)		VIII.	68	70	110	148	186	230
Average tractive force during accelerating period, in lbs. per ton (from Fig. 34A)		IX.	59	65	105	144	183	225
Tractive force during constant speed run (from Fig. 9)		X.	—	11·0	8·6	8·1	7·8	7·5
Maximum instantaneous power at axles per ton weight of train, at end of accelerating interval	In foot-pounds per second (IV. × VIII.)	XI.	6,000	4,400	5,650	7,150	8,750	10,500
	In kilowatts $\left(\frac{\text{XI.}}{737}\right)$	XII.	8·15	6·00	7·65	9·70	11·9	14·3
Average power at axles during acceleration per ton weight of train	In foot-pounds per second $\left(\frac{\text{IV.} \times \text{IX.}}{2}\right)$	XIII.	2,600	2,050	2,710	3,500	4,300	5,100
	In kilowatts $\left(\frac{\text{XIII.}}{737}\right)$	XIV.	3·53	2·78	3·68	4·75	5·85	6·93
Power at axles during constant speed operation, per ton weight of train	In foot-pounds per second (IV. × X.)	XV.	—	6·93	443	393	366	3·41
	In kilowatts $\left(\frac{\text{XV.}}{737}\right)$	XVI.	—	0·94	0·60	0·53	0·50	0·46
Energy expended at axles in watt hours per ton weight of train	During acceleration $\left(\frac{\text{XIV.} \times \text{V.}}{3·6}\right)$	XVII.	118	56	36	31	29	27
	During constant speed run $\left(\frac{\text{XVI.} \times \text{VII.}}{3·6}\right)$	XVIII.	—	25	28	28	28	27
	Total from start to stop (XVII. + XVIII.)	XIX.	118	81	64	59	57	54
Watt-hours expended at axles, per ton mile $\left(\frac{\text{XIX.}}{2}\right)$		XX.	59	41	32	30	29	27
Average power at axle, in kilowatts, for entire run between stops $\left(\frac{3·6 \times \text{XIX.}}{\text{VI.}}\right)$		XXI.	1·77	1·22	0·96	0·89	0·86	0·81
Ratio of maximum to average power at axles (XII. ÷ XXI.)		XXII.	4·6	4·9	8·0	11	14	18

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Rate of Acceleration (and Retardation).

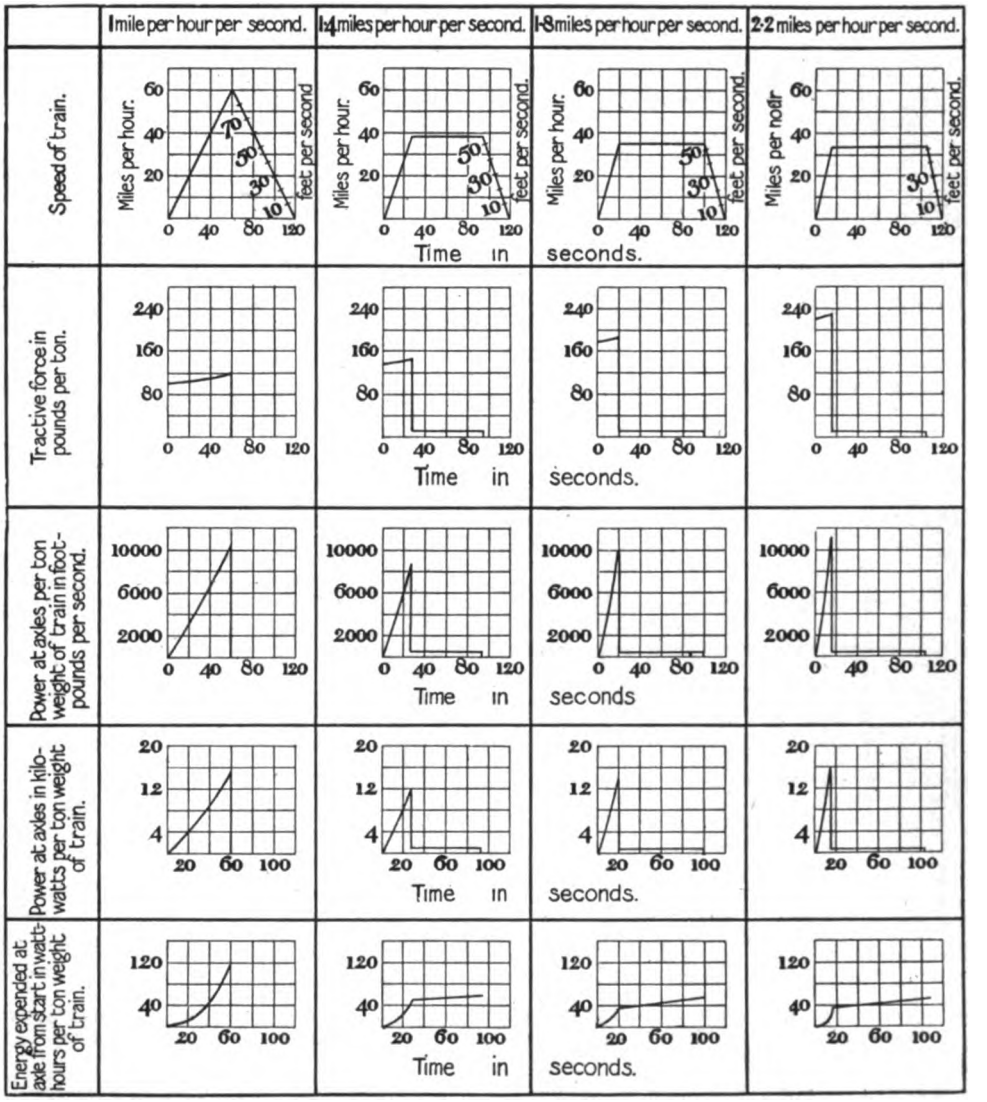
1 mile per hour per second.
1·4 miles per hour per second.
1·8 miles per hour per second.
2·2 miles per hour per second.
Speed of train.
Miles per hour.
feet per second.
Time in seconds.
Tractive force in pounds per ton.
Power at axles per ton weight of train in foot-pounds per second.
Power at axles in kilo-watts per ton weight of train.
Energy expended at axle from start in watt-hours per ton weight of train.

FIG. 35.—CURVES OF SPEED, TRACTIVE FORCE, POWER AND ENERGY AT AXLE.

200-ton train operated between stops at an average speed of 30 miles per hour, with one stop per mile.

work, it is also greater in a hilly district. While these articles relate to heavy electric traction, it will nevertheless be of interest to give curves based on results obtained in the authors' practice from comparative tests made by them upon tramcars equipped on the regenerative control principle and on the ordinary series-parallel control system. These curves are reproduced in Figs. 39 and 40. From the curves one sees that for relatively low schedule speeds and infrequent stops, the advantage of employing regenerative control becomes very slight; and taking into account the greater weight of a regenerative control equipment, the use of such a system would, in certain cases, even be a distinct disadvantage. On the other hand, a relatively high schedule speed, with frequent stops, permits of much greater advantages from the use of a regenerative control system than is generally realised. In fact, the brief periods of notoriety which these systems enjoy prior to disappearing from the scene, appear to be in considerable measure

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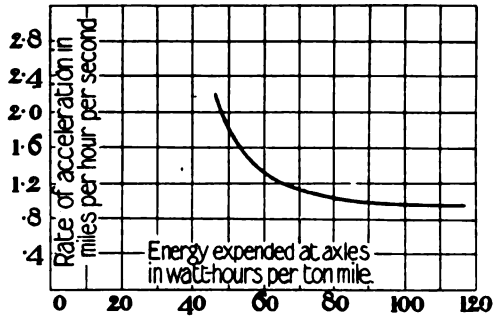

FIG. 36.—CURVE OF WATT-HOURS AT AXLES PER TON MILE.

200-ton train operating with one stop per mile, at an average speed of 30 miles per hour between stops: varying rates of acceleration.

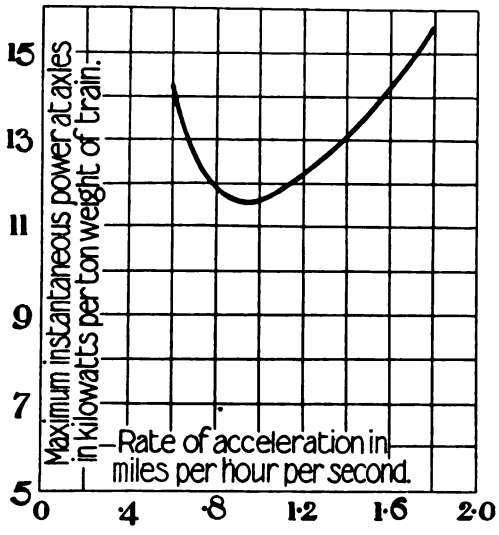

FIG. 37.—CURVE OF MAXIMUM INSTANTANEOUS POWER AT AXLES, IN KILOWATTS, PER TON WEIGHT OF TRAIN.

200-ton train operated with one stop per mile, at an average speed of 30 miles per hour between stops, for different rates of uniform acceleration. Rate of retardation taken equal to rate of acceleration.

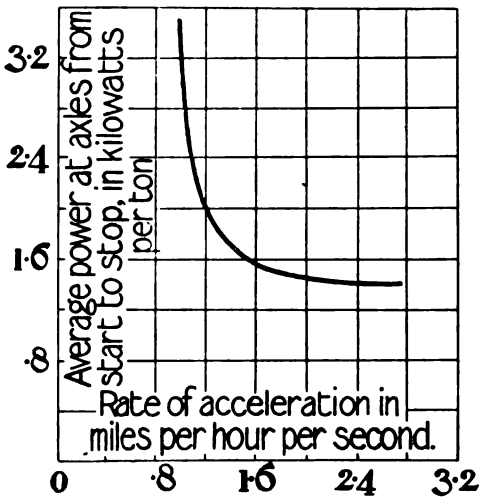

FIG. 38.—CURVE OF AVERAGE POWER, FROM START TO STOP, IN KILOWATTS AT AXLES, PER TON WEIGHT OF TRAIN.

Operated with one stop per mile, at an average speed of 30 miles per hour between stops, for different rates of uniform acceleration.

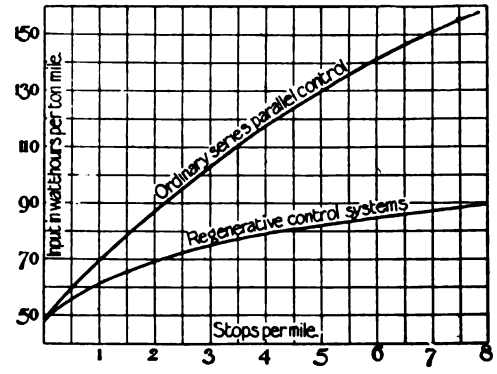

FIG. 39.—CURVES FOR TRAM CAR, OPERATED ON REGENERATIVE CONTROL SYSTEM.

Basis of Calculations:
Weight, Loaded Car—11 tons.
Car Friction—19 lbs. per ton excluding gearing.
Motor Efficiency—80 per cent. including gearing.
5 Second Stops.
Schedule Speed, 8 miles per hour. Level Track.

attributable to the failure to make exhaustive comparative tests of a character suitable to bring out clearly the considerable advantages which such systems would possess for certain cases. In view of the large amount that is written on this subject, the absence of a thorough recognition of the real conditions of success or failure forces the authors to conclude that their inventors and exploiters have not themselves yet arrived at a clear understanding of the matter.

There is another simple means of reducing the energy input to a certain extent. This consists in "drifting" or "coasting" to the destination, and decreasing the use of brakes; or, in other words, employing the train friction to brake the train. This has already been alluded to on pp. 425 to 428 of TECHNICS for November, 1904 (Vol. II., No. 5). The method of operation reduces the energy required at the axles, since the train friction is unavoidable, and might as well be

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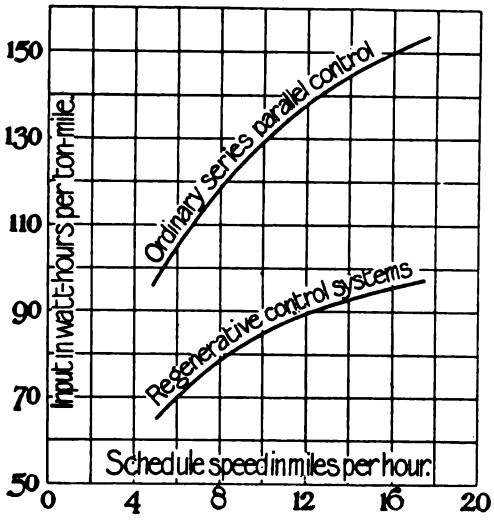

FIG. 40.—TRAM CAR. RELATIVE INPUTS AT DIFFERENT SPEEDS ON LEVEL TRACK.

Basis for Calculation:
4 *Stops per Mile.* *Weight, Loaded Car*—11 *tons.*
Car Friction—19 *lbs. per ton.*
Motor Efficiency, 80 *per cent.* 5 *Second Stops.*

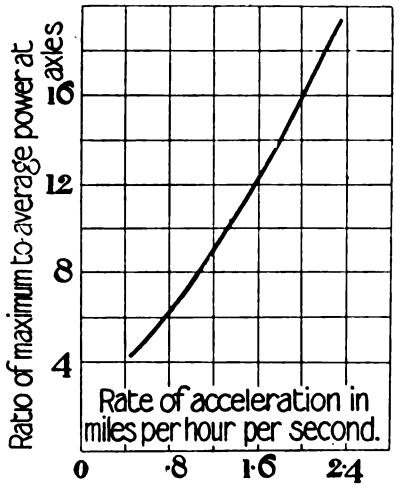

FIG. 42.—CURVE SHOWING RELATION BETWEEN THE ACCELERATING RATE, AND THE RATIO OF THE MAXIMUM TO THE AVERAGE POWER AT AXLES.

200-ton train operated with one stop per two miles, at an average speed of 30 miles per hour between stops.

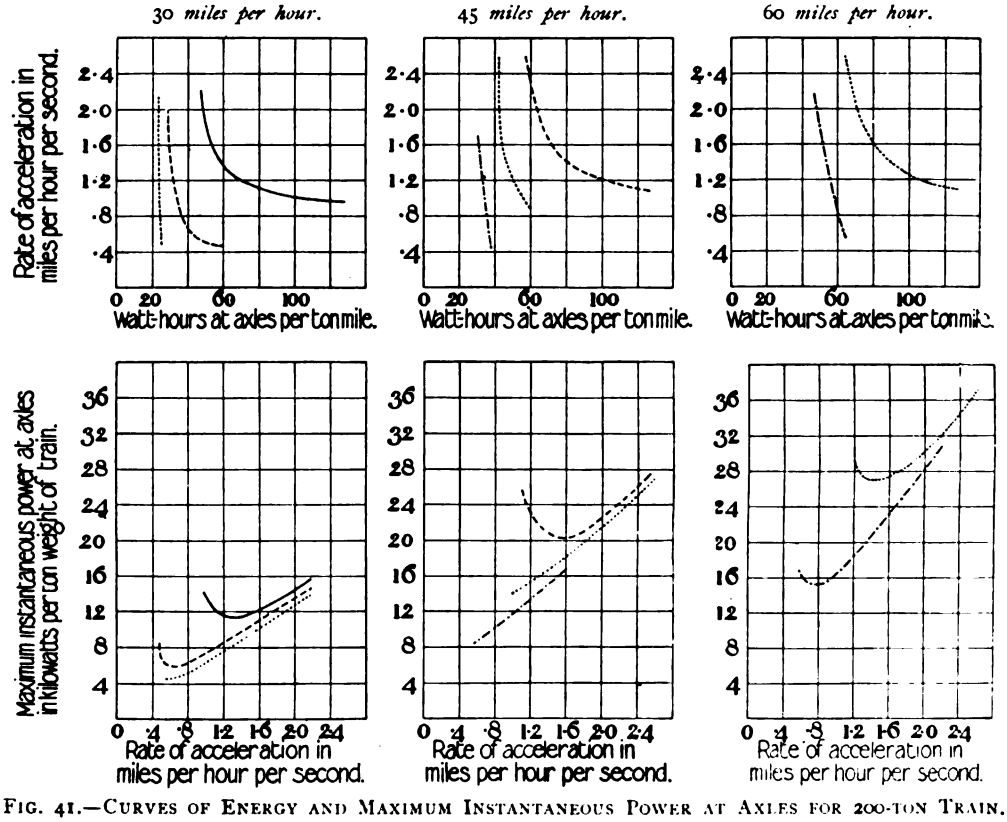

FIG. 41.—CURVES OF ENERGY AND MAXIMUM INSTANTANEOUS POWER AT AXLES FOR 200-TON TRAIN.

Curves for 1-mile run drawn thus ————
Curves for 2-mile run drawn thus — — — —
Curves for 4-mile run drawn thus . . . . . .
Curves for 8-mile run drawn thus —.—.—.

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employed to reduce the amount of energy required to be stored up in the train, only to be subsequently wasted at the brake shoes. By modifying the diagrams to take into account the further economy obtainable by substituting a "drifting" stage for the constant speed stage, a considerable reduction may be effected in the watt-hours per ton-mile for very short runs between stops, for the higher rates of acceleration; but for longer runs between stops the result will be relatively but slightly affected. This is also true of the economy attending "acceleration on the motor curve," a discussion of which must be deferred. The use of diagrams based on constant speed running and equal rates of acceleration and retardation has the advantage of giving a better defined basis for comparison of operation under various conditions as regards schedule speed, frequency of stops, and accelerating rate; it gives results on the safe side of the attainable values. The magnitude of the errors introduced by not taking advantage in these calculations of the further economies of "drifting" and of acceleration on the motor curve, will be discussed in a later section. "Drifting" has the advantage over regeneration that one avoids the loss of energy involved in reconverting mechanical into electrical energy. Advantage ought to be taken, according to the conditions, of both means of securing increased economy.

Calculations on the same lines as those set forth in Table VII. have been made for other speeds and frequency of stops, but it will only be practicable to give the final results as plotted in curves. In the upper row of curves of Fig. 41 is given the energy required at the axles in watt-hours per ton-mile corresponding to various rates of acceleration and to schedule speeds of 30, 45 and 60 miles per hour between stops, and for 1, 2, 4, and 8-mile runs.

In the lower row of curves of Fig. 41 are given, for these same conditions, the maximum instantaneous power at the axles in kilowatts per ton weight of train.

Item XXII. of Table VII. shows the dependence upon the accelerating rate, of the maximum to the average power at the axles for the two-mile run at an average speed of thirty miles per hour. The values are plotted in the curve of Fig. 42. Here we see plainly one of the disadvantages of a high rate of acceleration. It entails equipments of high maximum capacity, and also power-house plant and line with high maximum capacity, although the larger the number of equipments, the more will the disadvantages of a high ratio of maximum to average capacity be decreased, since the peaks of load of the different equipments will be so distributed as to give, at the power-house, a far lower value for the ratio of maximum to average load. Herein lies one of the great advantages of electric traction; for while, for such a service as that corresponding to the curve of Fig. 42, a steam locomotive would be obliged to provide energy at the axles at rates constantly varying through a wide range, an electric service, *with numerous trains fed from a single power-house* would give a *relatively* constant load on the prime movers at the power-house, and such a number of sets may at any time be placed in service as shall suffice to ensure operation at an economical range of loads.

Again, another reason for operating at low accelerating rates in steam service is seen from Fig. 42. Were a steam road to operate trains at a schedule speed of thirty miles an hour between stops, and with one stop every two miles, the moderate rate of acceleration of 1·4 miles per hour per second, would give a ratio of maximum to average load at axles, of over 10:1, and would entail very low economy at the locomotive. Somewhat higher rates of acceleration than this, and consequently higher schedule speeds, can, however, generally be economically provided for by electrical operation, where a frequent service is employed.

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MERCERISATION.

By B. J. EATON.

MERCERISATION is the name applied to the process of treating cotton and other vegetable fibres with strong solutions of caustic soda or potash, dilute sulphuric acid, and zinc chloride solution (the latter two to only a small extent), whereby the fibre is caused to contract in length, and its strength is increased; it also acquires a high lustre, and has an increased capacity for taking certain mordants and dyes.

The name "Mercerisation" originates from the discoverer of the effects above mentioned, namely, John Mercer, whose life and work (including his "Mercerisation" patent in 1850) are described in the following pages before discussing the chemistry and physics of the process.

MERCER AND HIS WORK.

John Mercer was born on February 21st, 1791, at Dean in the parish of Great Harwood, near Blackburn, and died on November 30th, 1866. His ancestors had been farmers for generations, though at the time of John Mercer's birth his father owned a small spinning mill, which he shortly afterwards had to give up, acquiring the lease of a small farm.

In 1799 the family suffered severely from the corn crop failure, and in 1800 the father died. Mercer, then nine years old, was sent to work as a winder, but soon had the opportunity of taking lessons from a designer—Blenkinsop—employed at the Openshaw Print Works; he showed great ability for mathematics. In 1807 he determined to learn dyeing, and finding that certain dye-woods and drugs could be obtained from a druggist in Blackburn, he invested all his money in three-pennyworths of eight or nine different samples, and began to experiment. He obtained satisfactory results, and opened a small dye house with a partner; he became so successful that Messrs. Fort, of the Openshaw Print Works, entered him as an apprentice in their colour shop in 1809.

Yours truly
John Mercer

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Owing to a great depression in the printing trade in 1810, his indentures were cancelled, and he had to return to hand-loom weaving, when he introduced new improvements in the loom and machinery. By the year 1813, he had saved sufficient money to start in business as a weaver and dyer, using waste material from the various print works. Up to this time he had merely worked by rule of thumb; but coming across Parkinson's "Chemical Pocket Book," he at once grasped the value of chemistry and its applications to dyers and printers, and he set to work to study the chemistry of textile manufacture and colouring, making his first notable discovery in 1817, when he produced an orange dye by padding with a solution of antimony sulphide, followed by passing the material through a weak solution of sulphuric acid.

This discovery was a great advance on the orange then obtained by mixing quercitron and madder.

As a result of this discovery he was at once engaged by Messrs. Fort and Company, as an experimental chemist, at 30*s.* per week.

From this time onwards he was constantly before the textile colouring trade as a clever experimenter.

He discovered the oxidising properties of a mixture of potassium chromate and sulphuric acid, and introduced it with great success as a discharge in dye vats.

He also found that metallic tin reduced indigo blue to indigo white in alkaline solution, and in 1823 he produced the "bronze styles," which are still made very similarly.

He discovered the use of oxalates in removing colouring matter from cochineal; although this largely-used dye-stuff was 10*s.* and more per lb., quite one-third of it was left in the dregs of the dye bath before Mercer's method was introduced.

In 1825 Messrs. Fort made him a partner in the firm, and this stimulated him to further experiments, so that in the next ten years he benefited the trade to a still greater extent.

He discovered a new method of fixing prussian blue, of discharging with potassium sulphocyanide, and of oxidising cutch with manganese salts.

He introduced sodium phosphate, and also, later on, sodium arsenate as a substitute for cow-dung—then largely used in fixing mordants—this being the subject of his first patent in 1839.

He then introduced alumina lakes for steam colour work, and in 1845 patented a process for making sodium stannate, cheaper and purer than the method then in vogue, and in a solid form.

Besides the discoveries above mentioned he made many others quite as notable, and in 1852 he was elected a Fellow of the Royal Society, having already been made a Fellow of the Chemical Society, and being one of its first members. Long before the process by which he is so well known, "Mercerisation," was a commercial success, his investigation of the action of the alkalis on vegetable fibres was looked upon by scientists and others as his *magnum opus*.

His work in connection with the process of "Mercerisation," beginning with the original patent, is treated in the following pages, together with the work of later experimenters who have confirmed and augmented his researches.

Mercer's Specification (13296—1850).

In this quaintly-worded document, John Mercer, of Oakenshaw, within Clayton-le-Moors, gentleman, sends greeting "to all to whom these presents shall come," and informs them that a monopoly in his invention of "Improvements in the preparation of cotton and other fabrics and fibrous material" has been granted to him for a term of years to "make use, exercise, and vend within England, Wales, and the Town of Berwick-on-Tweed, providing that he describes his invention." This he proceeds to do in the following terms:—

"My invention consists in subjecting vegetable fabrics and fibrous materials, cotton, flax, etc., either in the raw or manufactured state, to the action of caustic soda or caustic potash, dilute sulphuric acid, or chloride of zinc, of a strength and temperature sufficient to produce the new effects, and to give the new properties to them which I have hereafter described.

"The mode I adopt of carrying into operation my invention to cloth made wholly or partially from any vegetable fibres and bleached, is as follows:—

"I pass the cloth through a padding machine, charged with caustic soda or caustic potash, at 60° or 70° Twaddel's hydrometer, at the common temperature, say 60° Fahrenheit or under, and, without drying the cloth, wash it in water, then pass through dilute sulphuric acid and wash again; or I run the cloth over and under a series of rollers in a cistern with caustic soda or caustic potash, at from 40°–50° of Twaddel's hydrometer, at the common temperature of the atmosphere, the last two rollers being set so

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as to squeeze the excess of soda or potash back into the cisterns charged at the commencement of the operation with water only, so that at the last cistern the alkali has nearly all been washed out of the cloth. When the cloth has either gone through the padding machine, or through the cisterns above described, I wash the cloth in water, pass it through dilute sulphuric acid, and wash again in water.

"When I adapt the invention to grey or unbleached cloth made from the fibrous material before mentioned, I first boil or steep the cloth in water, so as to have it thoroughly wet, and remove most of the water by the squeezers or hydro-extractor, and then pass the cloth through the soda or potash solution, etc., and proceed as before described.

"I apply my invention in the same way to warps either bleached or unbleached, but after passing through the cistern containing the alkali the warp is either passed through squeezers or through a hole in a metallic plate, to remove the alkali, and then passed on through the water cisterns, soured and washed as above described.

"When thread or hank yarn is operated on, I immerse the threads or yarns in the alkali and then wring them out, as is usually done in sizing or dyeing them, and afterwards wash, sour, and wash in water as above described.

"When I apply my invention to any fibre in the raw state, or before it is manufactured, I first boil it in water, and then free it from most of its water by the hydro-extractor or a press. I then immerse it in the alkaline solution, and then remove the alkali by the hydro-extractor, or I press the alkali out with a press and then wash in water, sour in dilute sulphuric acid, wash again, and then remove the water by a press or hydro-extractor as above described.

"When cloth made from vegetable fibre, cotton, flax, etc., has been subjected to the action of caustic soda or potash, as above described, by padding, immersion, or any other way, and then freed from the alkali by souring and washing according to my said invention, the cloth will be found to have undergone certain changes and alterations, and to have acquired certain new and valuable properties. The most remarkable I here describe.

"It will have shrunk in its length and breadth, or have become less in its external dimensions, but thicker and closer, so that by the chemical action of caustic soda or potash, I produce on cotton and other vegetable fabrics and fibres effects somewhat analogous to that produced on woollen by the process of fulling or milling.

"It will have acquired greater strength and firmness, each fibre requiring greater force to break it. It will also have become heavier than it was before it was acted on by the alkali, if in both cases it be weighed at the temperature of 60° Fahr. or under. It will have acquired greatly augmented and improved power of receiving colours in printing and dyeing.

"The effects of the application of my invention to the vegetable fibre in any of its various stages, before it is manufactured into cloth, will be readily understood by reference to its effects upon cloth composed of such fibres.

"Secondly, I employ sulphuric acid diluted to 105° Twaddel's hydrometer, and the heat not above 50° Fahrenheit, lest the animal fibres should be injured.

"I may, in conclusion, remark that the description of the apparatus or machinery, and the strength and temperature of the soda or potash, sulphuric acid or chloride of zinc solution, may be varied to a considerable extent, and will produce proportionate effects without at all deviating from my invention. For instance, caustic soda or potash may be used even as low as 20° Twaddel's hydrometer, and still give improved properties to cotton, etc., in receiving colours in printing and dyeing, particularly if the heat be low, for the lower the temperature the more effectively the soda or potash acts on the fibrous material above described.

"I, therefore, do not confine myself to any particular strength or temperature of the substances I employ, but the particular strength, heat, and process here described is what I have found the best, and which I prefer.

"And I claim as of my invention the subjection of cotton, linen, and other vegetable fibrous material, either in the fibre or any stage of its manufacture, either alone or mixed with silk, woollen, or other animal fibrous material, to the action of caustic soda or caustic potash, dilute sulphuric acid, or solution of chloride of zinc of a temperature and strength sufficient to produce the new effects, and give to them the new properties above described, either by padding, printing, or steeping, immersion, or any other mode of application."

Originality of Mercer's Process Challenged.

Several contemporary writers affirm that something was known of the action of alkaline

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lyes on cotton before Mercer's experiments were conducted. O'Neill, writing in 1860, says a passage in Persoz's "Traité Théorique et Pratique de l'Impression des Tissus" proves this to be so; but the editors of the *Dyer and Calico Printer* say they have failed to find the passage thus referred to by O'Neill.

A Nurnberg firm, Leuchs & Co., claim the discovery as their own, as seen in a letter in *Dingler's Polytechnisches Journal* of 1851, Vol. 122, p. 318.

They say it was communicated to them by Professor T. Leykauf in 1845, and made public in the *Polytechnische Zeitung* of Jan. 28th, 1847, published by themselves.

The technical press of Germany, however, did not support their claim of priority, and acknowledged the fact also that Mercer commenced his work in 1844. Leibig and Kopp, in the *Jahresbericht* of 1851, say it is impossible to gather that their process was the one patented by Mercer, or that it was invented by Leykauf.

The *Deutsche Muster Zeitung*, now the *Leipziger Färber Zeitung*, which appeared in 1851, was the first paper to note Mercer's invention in their sixth issue of that year.

Reasons of Non-success of the Process.

O'Neill, in 1862, makes the following comments:—

The action of caustic lyes of 50° Twaddel's strength and upwards on cotton, etc., would not have been anticipated, and the invention came as a surprise, for it was accepted as an axiom that, as even rather weak caustic soda solutions dissolved up silk and wool, and if allowed to act for a long time also disintegrated cotton; therefore the action of strong caustic soda solutions must be destructive to cotton fibres, and this was supported by the appearances seen when a bit of calico accidentally fell into strong caustic soda and curled up, appearing to be destroyed, and becoming translucent, as though tending to dissolve.

Mercer, however, proved that the only change was a contraction and consequent thickening of the fibre.

Yarn, woven or unwoven, became less opaque after treatment, and became rounder and firmer, the cloth appearing finer, and the dimensions contracting about 1 in 15.

The cotton thus treated took both mordants and dyes somewhat better than untreated cotton, the difference being one of depth rather than quality.

The Mercerised cotton, as it was called, showed a remarkably increased power of absorbing indigo from the ordinary blue vat, taking up in the same time as much as yields a shade three or four times darker than acquired by ordinary cotton.

It was found impossible to make any use of the process at the time, in spite of its brilliant prospects, because, in the first place, the initial cost was considerable, but chiefly because no exceptional effects could be produced which seemed worth the expense. Caustic soda, too, was not an article of commerce in Mercer's time; up till the year 1861 most of the caustic soda produced was "cream soda," *i.e.*, soda concentrated till it set on cooling, but not by fusing.

In 1866, *the earliest date of any quotation for soda, the price of* 70 *per cent. soda was* £26 *per ton.* This in itself is sufficient to explain the non-success of the process in Mercer's time.

The price of zinc chloride was even more prohibitive, and no special advantages were gained by its use, while the use of the much cheaper sulphuric acid was not trustworthy, owing to the great care required, and risk of injuring the fabric.

As a process, "Mercerisation" nearly died out in the thirty years following the date of Mercer's patent; his name became almost forgotten, and the process was only remembered as one interesting but unsuccessful.

Craping and Lustring.

Experimenters, however, were still quietly at work endeavouring to develop the patent for commercial uses, especially with regard to what may be called the second stage of Mercer's process—"craping."

In 1867, Meyer Rauschenbach re-patented a part of Mercer's specification in England, using sulphuric acid of about 105° Tw. at a reduced temperature for stiffening yarn and cloth.

A fresh epoch in the history of the process was created by Garnier and Depoully's patent in 1883, in which a process was given for strengthening cotton cloth, chiefly the lighter fabrics, gauze and muslin, using caustic soda lye of 30°–36° B.

It was stated that the fabric then resisted the pressure of the engraved rollers used in printing without being torn, and also that a high lustre was given on the side pressed by the cylinders. The authors in this patent practically recognised and foreshadowed the third stage of Mercer's process—"lustring." They, however, with other patentees at that time, were only endeavouring to obtain the craping or crimpling effects then in fashion.

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This craping effect was obtained by mercerising alternate layers or threads of the cloth, using a resist to prevent the action of the caustic soda on the part not to be contracted. In this way contraction was obtained for alternate layers of the fabric, producing the well-known crimpled or craped effects.

In 1884, Depoully brought out a second patent for crimpled cloth, in which he either used one material such as cotton, or in which the fabric was a mixture of two materials, such as silk and cotton.

The "crepon" effects were in the height of fashion when the third stage of the process known as "lustring" was reached.

The credit of observing and producing "lustring" effects is due to several investigators, the discovery being purely accidental. The effect, again, is merely a part of Mercer's original process, and is obtained by stretching the fabric during the process of Mercerisation.

The first patent was that produced by Lowe, in 1889, using caustic soda of 25°–75° Tw., acting for two minutes at 60° Fahrenheit generally, but the action may vary from 1 to 15 minutes according to the character of the fibre, bulk of material, and strength of lye. The fabric, after this alkaline treatment, was passed through wringing rollers, then rinsed with warm water.

In 1890 Lowe produced another patent, and in 1895 Thomas and Prevost patented a similar process with different conditions, the only differences produced being in quality of lustre, etc. Altogether, from the date of Mercer's first specification in 1850, to the last patent taken out at the end of June, 1902, no less than 170 patents have been produced bearing more or less on the process, and practically all of these are included in Mercer's own specification as given in the original.

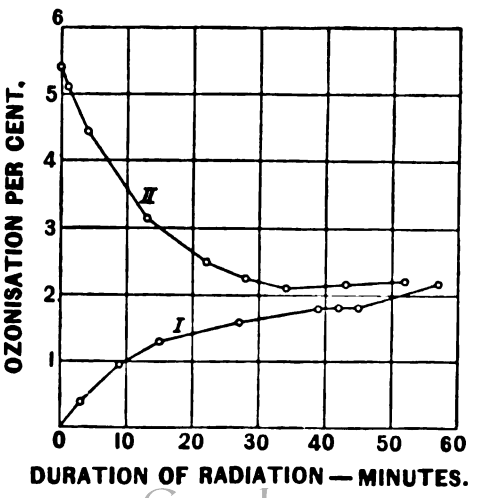
The process in its various stages is a commercial success, and is practised by many large textile manufacturers, printers, and dyers at the present time, many factors combining to produce this success.

(*To be continued.*)

OZONE.

THE rapidly increasing applications of ozone for commercial purposes have led to many experiments with reference to its production both by electrolysis and by means of the so-called "silent discharge." When produced electrolytically 96,540 coulombs are theoretically required for the formation of 24 grams of ozone. The current actually required is several times greater, but the voltage used is small, and the consumption of power is therefore not excessive. Warburg has recently shown that when produced by means of a point discharge the same quantity of ozone only consumes 92 to 500 coulombs, though at a vastly higher potential. These experiments demonstrate clearly the fact that the action of the discharge is not electrolytic, and Professor Warburg ascribes the production of ozone to the effect of light-rays or kathode rays produced by the discharge.

Very similar effects are produced by the radiation from a spark discharge. In pure oxygen this radiation produces ozonisation to the extent of 2·2 mols. of ozone per 100 mols. of oxygen, but when ozonised oxygen is exposed to the radiation it is rapidly deozonised until the percentage of ozone falls to the value given above. The ozonising and deozonising effects of the radiation are clearly shown in the accompanying figure curves II and I respectively. The radiation which produces these effects passes readily through quartz, but is entirely stopped by glass.



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CYCLE CHANGE-SPEED GEARS.

By ARCHIBALD WILLIAMS.

CHANGE-SPEED gears are no novelty in mechanics; for decades they have been used on traction engines, chaff cutters, and other machines. Their successful application to cycles dates from but a few years ago: nevertheless, the buyer may now take his pick from a dozen devices, all carefully thought out, accurately constructed, and each possessing a high efficiency.

I now propose to examine the nature and action of four typical change speed gears—the "Hub," the "Fagan," the "Sturmey-Archer," and the "Pedersen." The first two give the rider a choice of two gears, the two last of three gears. As all are based upon the use of an "epicyclic train," it will be fitting to preface the detailed description of each individual gear by a general consideration of epicyclic gearing.

Lay a foot-rule on the table, and roll a cylinder along it by the aid of a second rule, parallel to the first, but resting on the cylinder. It will be found that, while the cylinder advances six inches, the upper rule advances twice that distance. In the absence of friction the work done by the agent moving the upper rule is equal to that done in overcoming the force which opposes the forward motion of the cylinder; and as the distance through which the cylinder advances is only half that through which the upper rule advances, it follows that the force which must act on the upper rule is only half as great as that overcome in moving the cylinder forward. The carter makes use of this principle when he puts his hand to the top of a wheel to help his cart over an obstacle.

To render the rolling of the cylinder mechanically effective, its circumference must be provided with teeth, engaging with similar teeth in the bed over which it moves, and with the rack which moves it.

For the purposes of cycle gearing, the bed is replaced by a fixed pinion, and the rack by an annulus carrying teeth on its inner side. Referring to Fig. 1*a*, we have X, the outer annulus, Y, the rolling pinion, and Z, the fixed pinion. To understand exactly how this combination works, let us first suppose that the axis of the pinion Y is fixed in space, the pinion being, however, capable of rotating about this axis. Further, let us suppose that the inner pinion Z and the annular rack X are perfectly free to rotate, and that the number of teeth on Z is *t*, while the number on X is T. Then if the pinion Y has *n* teeth, a complete clockwise rotation of Y about its stationary axis will cause *n* teeth to engage in succession with the teeth of X, and the annular rack will therefore advance by *n* teeth, or by (n/T) of a complete rotation in a *clockwise* direction (Fig. 1*b*). At the same time, *n* teeth of the inner pinion Z must have been engaged in succession, and Z must have rotated through (n/t) of a complete rotation in an *anti-clockwise* direction.

To pass to the case where the inner pinion is stationary, and the axis of Y is free to move, let us now suppose that the whole arrangement is rotated as a single body about the centre of Z through (n/t) of a complete clockwise rotation (Fig. 1*c*). This

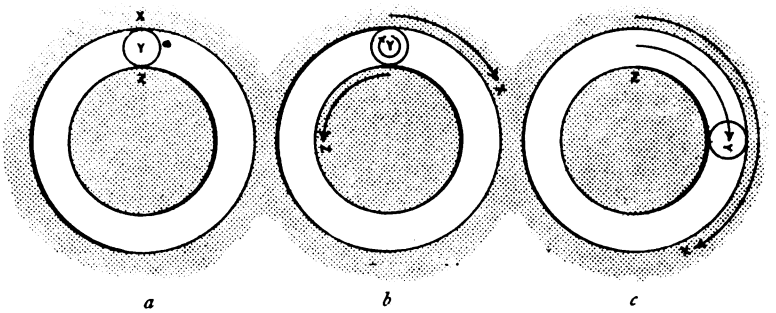

FIG. 1.—TO EXPLAIN PRINCIPLE OF ACTION OF AN EPICYCLIC TRAIN OF WHEELS.

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will bring the central pinion Z to its original position; the axis of Y will have revolved about the centre of Z through (n/t) of a complete clockwise revolution; and the rack X will have rotated about the centre of Z through the sum of the angular displacements imparted to it, *i.e.*, through $\left(\frac{n}{t}+\frac{n}{T}\right)$ of a complete clockwise rotation. Thus—

$$\frac{\textit{Angular displacement of } X}{\textit{Angular displacement of axis of } Y} = \frac{\frac{n}{t}+\frac{n}{T}}{\frac{n}{t}} = \frac{\frac{t+T}{tT}}{\frac{1}{t}} = \frac{t+T}{T}.$$

From this it is clear that if the central pinion Z is maintained stationary while the annular rack is rotated at any given speed, the pinion Y being free to roll as the conditions require, then while Y rolls once completely round Z, the annular rack X will make $(t+T)/T$ rotations. Thus we have—

$$\frac{\textit{Speed of rotation of } X}{\textit{Speed of revolution of } Y} = \frac{t+T}{T}.$$

If the motion of Y is opposed by a given force, and a motive force acts on X, then—

$$\frac{\textit{Force acting on } X}{\textit{Force opposing motion of } Y} = \frac{T}{t+T}.$$

To proceed to an example: If X has fifty teeth, and Z twenty-five teeth, one revolution of the axis of Y about the centre of Z implies $\frac{50+25}{50} = 1\frac{1}{2}$ rotations of X; and conversely, one rotation of X $= \frac{50}{50+25} = \frac{2}{3}$ revolution of Y.

If a given motive force be applied to X, this will be capable of overcoming a force 50 per cent. greater opposing the motion of Y, and the speed of Y will be less than that of X by $33\frac{1}{3}$ per cent.; if the force is applied at Y's centre, there will be a speed gain of 50 per cent., and a diminution of force of $33\frac{1}{3}$ per cent. with regard to X.

Should X and Z be mechanically connected so as to form a rigid whole, Y obviously can no longer roll round Z. In general, if *any two* of the three elements X, Y, and Z are rigidly connected, the combination can move only as a solid body.

Taking advantage of this, the "Hub" and "Fagan" two-speed gears are so contrived that Z can be maintained fixed in space and independent of X; or fixed to, and free to rotate with X, at the will of the rider. The same end is attained in each case by rather different means, as will be understood from the illustrations (Figs. 2 and 3) and the following short explanations.

THE "HUB" TWO-SPEED GEAR.

Fig. 2 represents this gear in section. The

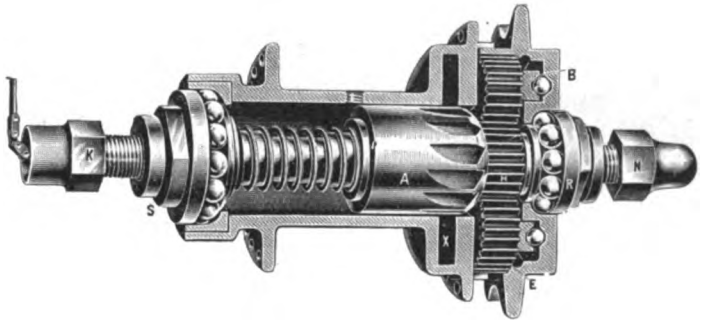

FIG. 2.—THE "HUB" TWO-SPEED GEAR.

sprocket wheel to the right (equivalent to X, Fig. 1) has sixty-four internal teeth, and gears with four planet pinions E, revolving on studs formed out of the solid metal of the hub. Each of these planet pinions corresponds to Y, Fig. 1; four are used in order to minimise the wear on each. The four planet pinions gear with the central pinion H (equivalent to Z, Fig. 1), which is free to rotate round the axle. The central pinion H has twenty teeth, and is made longer than required for gearing with the planet pinions; its end fits into the interior of the sliding clutch A, which is provided with internal teeth, and ratchet teeth cut upon its outside surface. Two free-wheel pawls are pivoted in the annular groove X; these engage with the ratchet teeth on the outside of the sliding clutch A.

On turning the sprocket wheel the pinion H would rotate in an opposite direction to the hub, were it not prevented from doing

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so by the free-wheel pawls engaging with the ratchet teeth of A, which force the clutch A, and therefore the pinion H, to rotate with the sprocket wheel. Hence, two of the elements of the epicyclic train are rigidly connected, and consequently the whole combination rotates as a whole. This gives the top speed.

When the cycle is in motion, if the rider ceases pedalling, the ratchet teeth allow A to rotate and so give a free-wheel action.

To obtain the low speed, A is pulled to the left by means of the small chain running through the hollow spindle; this action causes the toothed interior of A to engage with teeth on the spindle, and also brings A clear of the free-wheel pawls situated in the groove X. A still engages with the teeth of H, which thus becomes fixed with regard to the spindle; the sprocket wheel is able to rotate independently, so that—

$$\frac{\textit{Velocity of sprocket wheel}}{\textit{Velocity of pinions E}} = \frac{T + t}{T} = \frac{64 + 20}{64} = \frac{84}{64},$$

or the hub rotates at a rate 23·8 per cent. lower than the sprocket wheel. On the low speed, free-wheeling is impossible.

Fagan Gear.

This gear (Fig. 3) has a sprocket working the driving annulus by a Hyde free-wheel attachment. The annulus has sixty-four internal teeth, which gear with four planet pinions rotating on pins forming part of the hub-shell. The central pinion has twenty teeth; in Fig. 3 it is shown loose on the spindle, but it is normally pressed towards the left, so as to engage with the internal teeth of a collar solid with the spindle. In these circumstances the central pinion is fixed, and the low gear is obtained in accordance with the equation—

$$\frac{\textit{Velocity of sprocket wheel}}{\textit{Velocity of planet pinions}} = \frac{64 + 20}{64} = \frac{84}{64},$$

as in the case of the "Hub." To throw in the high, or solid gear, the rider, by means of a cable, raises the small bell-crank lever and pulls the central pinion to the right into engagement with teeth on the interior of a central opening, the driving ring causing it to rotate with the annulus.

As the annulus can overrun the sprocket, free-wheeling is possible on both speeds.

Sturmey-Archer Gear.

The sectional illustration, Fig. 4, represents the Sturmey-Archer speed gear: as this is somewhat complicated, two additional cuts

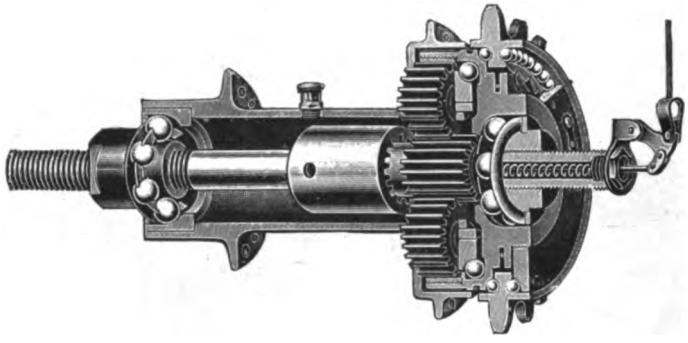

Fig. 3.—"Fagan" Two-speed Gear.

(Figs. 5 and 6) are given, showing the most important parts of the gearing separated. (The same lettering has been adopted in all three illustrations, to prevent confusion.) It should be mentioned that Fig. 4 is not quite accurate in all its details; thus, the pins LL, on which the planet pinions G revolve, are in reality small enough to slip into the recesses E of the free-wheel clutch C.

In the two-speed gears already described, the high gear is solid, and the low gear produced by the action of the epicyclic train. A third speed can obviously be obtained by applying the driving force to the Y element (Fig. 1), *i.e.*, to the pins on which the planet pinions revolve; and at the same time connecting the X element with the hub shell.

Referring to Figs. 4, 5, 6, the plate N, which screws into the left end of the hub shell with a left-handed thread, has studs on its inner face (*see* Fig. 5). The other end-plate is provided with internal teeth K, engaging

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with the external teeth Q of the gear-box ring I; further, I has internal teeth O to engage with the external teeth of the clutch ring C. The ring I, which corresponds to X, Fig. 1, drives the four planet-pinions G (corresponding to Y, Fig. 1), and transmits movement to the studs L, and thence to the long barrel terminating at the left end in teeth M. The central spindle is provided with teeth F, and corresponds to Z, Fig. 1. The springs R and T tend to force the planet cage I, the pinions G, and the barrel carrying M towards the right. Fig. 4 shows the lowest gear in action, the planet cage I, the pinions G, and the barrel being pulled to the left by

On the change-speed wire being slackened the planet cage slides towards the right, releasing the teeth M from the studs on N. Simultaneously the teeth Q (Figs. 4 and 6) engage with the internal teeth of the hub-shell at K, thus effecting a direct drive from C to I and thence to the hub-shell; the Y element of the epicyclic train (pinions G) now revolves idly in space.

A further slackening of the wire causes the pins L to slip into the recesses E of the free-wheel clutch C; meanwhile the teeth O of the planet cage pass beyond the exterior teeth of C. The drive is now transmitted from C to the pins L, thence to the pinions G,

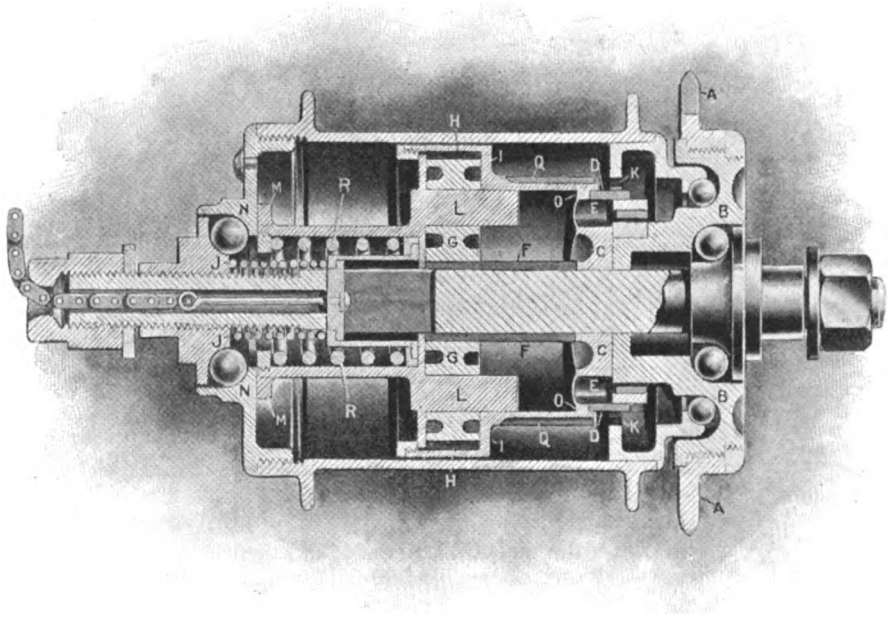

Fig. 4.—Section of Sturmey-Archer Three-speed Gear.

means of the chain in the interior of the axle; in this position the teeth M gear with the studs on N. The chain wheel A, connected with the free-wheel C, imparts motion by means of the exterior teeth of C to the planet-cage I, which in turn transmits the power *viâ* the pinions G and the studs L to the barrel-teeth M, and thence by the studs on N to the hub shell. The internal teeth of I, gearing with the planet pinions G, are 64 in number, and the exterior teeth of the central fixed pinion F are 16 in number:

$$\frac{\textit{Velocity of A, C, or I}}{\textit{Velocity of barrel or N}} = \frac{64+16}{64} = \frac{10}{8}$$

so that the speed of N is 20 per cent. lower than that of the driving wheel A.

and through these to I, which, being still meshed with the hub-shell by its long external teeth engaging with the interior teeth of the shell, causes the latter to revolve.

$$\frac{\textit{Velocity of I}}{\textit{Velocity of A, C, or G}} = \frac{64+16}{64} = \frac{10}{8}$$

so that the hub rotates at a rate 25 per cent. greater than the speed of the driving-wheel A. Then it will be noticed that the teeth F of the spindle are long enough to be meshed with the interior teeth of the fixed pinion G during the operation of all three gears.

The gears have the proportion of 25:20:16, and are actuated through a Bowden cable and a trigger on the handle-bar. The free-wheel is, of course, available at all gears.

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Pedersen Gear.

Figs. 7 and 8 illustrate the Pedersen three-speed gear. This device resembles the Sturmey-Archer in the fact that the middle speed is the normal, or "solid": but differs from it, and the Hub and Fagan, in the arrangement of the epicyclic train wheels.

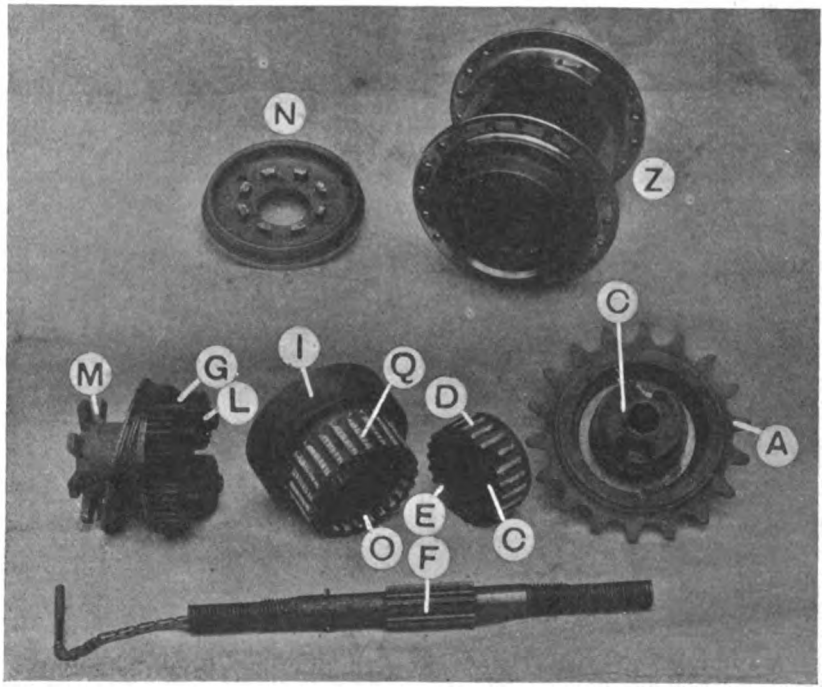

Fig. 5.—Parts of Sturmey-Archer Gear.

Fig. 7 shows the gear with part of the shell F cut away. B is a spur wheel and sleeve provided with internal guides which slide in slots on the main spindle A. The rider actuates this wheel by means of a gear change lever, a wire cable, and the small chain which is shown passing into the hub. When the wheel B is in the position shown in Fig. 7, the middle gear is in operation, and the whole hub runs solid. The plates I and H encircling the shell are extended on one side so as to give bearings for a secondary spindle and spur wheel M, and also for a loose pinion R, which is permanently in gear with the smaller of the two pinions of the loose collar O. The clutch N (solid with M) drives the friction clutch P, and forces it tightly into O when rotated backwards, thus making O for the time solid with M.

The clutch ring L has two sets of teeth, those on the right engaging with a similar set attached to the hub shell, while those on the left engage with projections on the inner side of the main spur wheel K. This ring can be thrown out of action by pressing the three studs E towards the left.

To obtain the high gear, the wheel B is allowed to slide till it engages with the larger pinion of O. The drive is communicated by K to M, and thence to clutch N; thence to taper friction clutch P, which in turn drives the double spur wheel O.

K has 36 teeth; M has 17; O (large pinion), 28; B, 20.

To find the resultant gear, we may proceed as follows. Suppose the axis of M and O to

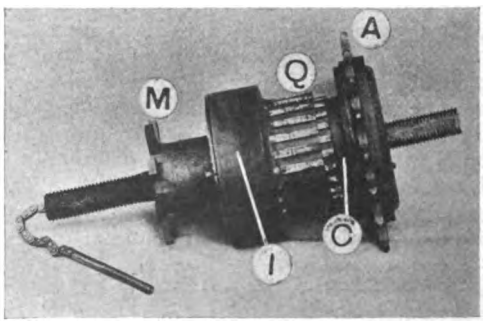

Fig. 6.—Some Parts of Sturmey-Archer Gear, partially assembled for use.

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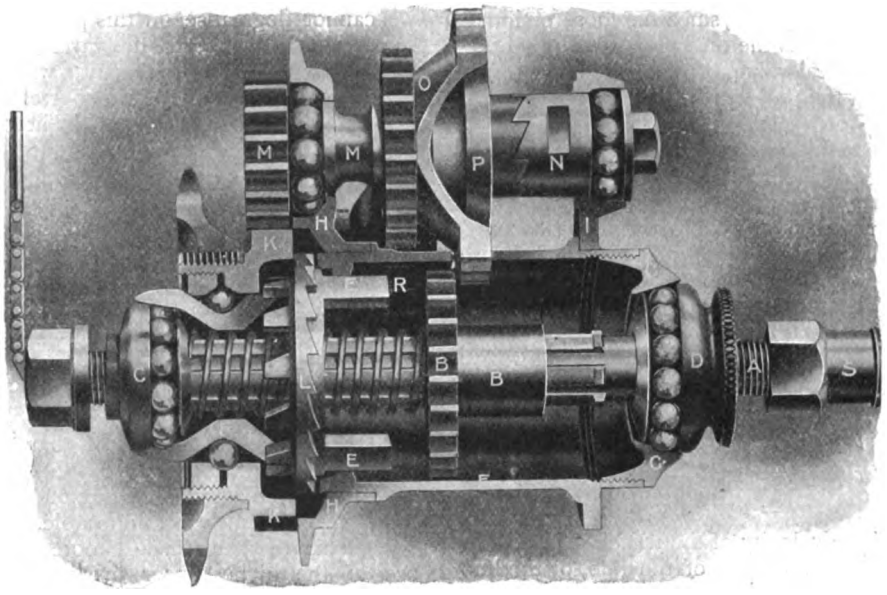

FIG. 7.—PEDERSEN GEAR.

remain stationary above the main axis A, while the large pinion O is rotated through a complete clockwise turn; then, since O has 28 teeth and B has 20 teeth, B will turn in an anti-clockwise direction through (28/20) of a complete rotation. At the same time, since M has 17 teeth, and K has 36 teeth, K will turn through (17/36) of a complete anti-clockwise rotation. In practice the wheel B remains stationary. To pass to this condition, suppose that the whole arrangement is turned as a solid body through (28/20) of a clockwise rotation, so as to bring B back to its original direction. In this process the axis of O and M, and with this the hub, turns through (28/20) of a clockwise rotation. K has turned through (17/36) of an anti-clockwise rotation, and subsequently through (28/20) of a clockwise rotation, the resultant displacement being (28/20) − (17/36) = (334/360) of a complete clockwise rotation. Thus,

$$\frac{\textit{Displacement of hub}}{\textit{Displacement of K}} = \frac{28}{20} \div \frac{334}{360} = \frac{252}{167}$$

$$= 1 \cdot 50 \text{ (nearly).}$$

Thus the gain in speed is practically 50 per cent.

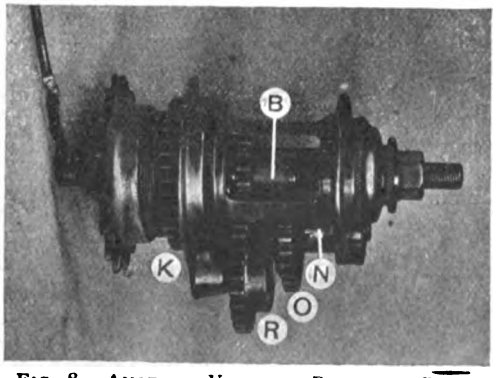

FIG. 8.—ANOTHER VIEW OF PEDERSEN GEAR, SHOWING LOOSE PINION R.

While the hub shell is overrunning the main spur wheel, the clutch L is inert. But when B is traversed to produce the middle gear, the inner teeth of K press upon the left teeth of L with a wedging stress, and force the right teeth into the clutch on the shell. In these circumstances the drive is direct from K to the hub shell. When the rider ceases pedalling, the clutch permits the hub to overrun the sprocket and its attachments.

A further pull to the left brings B into gear with R, already engaged with the smaller pinion of O. B presses on the studs E, and throws the clutch L out of action.

The motion is now: K drives M; M drives O; O drives R; M, O, and R revolve around B.

R, as an intermediate pinion, reverses the direction of M's rotation with regard to K; O has 19 teeth. To analyse the gear, let us suppose that the axis of M and O remains stationary above the axis A, and that one complete clockwise turn is given to the small

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pinion of O. Then, since the loose pinion R merely reverses the direction, without altering the numerical value, of the rotation imparted to B, it follows that B will rotate through (19/20) of a clockwise turn. As before, K will rotate through (17/36) of an anti-clockwise turn. To pass to the condition where B is stationary (as in practice), turn the whole arrangement as a solid body about the axis of A, through (19/20) of an anti-clockwise turn. B will be brought back to its original position; the hub shell will have turned through (19/20) of a complete anti-clockwise rotation; while K will have turned through $\{(17/36) + (19/20)\} = (64/45)$ of an anti-clockwise turn. Thus

$$\frac{\textit{Velocity of } K}{\textit{Velocity of hub shell}} = \frac{64}{45} \div \frac{19}{20} = \frac{256}{171}$$
$$= 1{\cdot}5 \text{ (nearly)},$$

so that the velocity of the wheel K is 50 per cent. higher than that of the hub, or the hub rotates at a rate nearly 33 per cent. less than that of K.

Criticism of Gears.

The above accounts have been written after a careful dissection of the gears themselves. As pieces of mechanism they all show a high finish. Theoretically, at least, the Pedersen would seem to have an advantage over the Sturmey-Archer as regards the amount of friction set up by the rotating parts, as will be seen by reference to the diagrams. In the case of the Pedersen device, all moving surfaces (except, of course, the teeth) are kept apart by ball bearings; whereas in the Sturmey-Archer there are, on the high speed, one clutch and four planet pinions revolving on plain bearings, and the collar I rubbing on the clutch C. On the other hand, the Sturmey-Archer is neater in appearance than the Pedersen, and less accessible to dust. In practice, it would be hard to decide the respective merits of the gears. The Fagan has, it is true, a free-wheel action on both speeds, the Hub only on the high speed. If a free wheel is an advantage under all conditions, then the Fagan has in this respect a superiority. People will be found, however, who prefer a fixed wheel at times; so we cannot dogmatise on this point. Again, some riders may declare the variations of the Pedersen speeds to be too great; while others will consider that the Sturmey-Archer does not vary to a sufficient extent. These points are more or less a matter of taste.

It will, nevertheless, be admitted that a good three-speed is better than a good two-speed gear, since the former enables the rider to keep the normal (solid and, therefore, practically frictionless) gear for ordinary use, with the high in reserve for favourable, and the low for unfavourable conditions. The writer has made practical tests of all four gears on the road, and his experiences lead him to the following conclusions:—

(*a*) That the advantages of change-speed gears are so marked as to be beyond question.

(*b*) That the amount of friction set up by the epicyclic train is not noticeable.

(*c*) That the rider makes more and more use of the highest gear over good, level roads. This tends to prove that a fixed gear sufficiently low for climbing moderate hills is not entirely adapted for ordinary riding on the level.

(*d*) That the high gear of the three-speed shows to especial advantage in the descent of gentle declines.

(*e*) That the uncomfortable feeling which at first accompanies a "step-down," and the consequent quickening of the pedalling rate, soon disappears with use.

(*f*) That a change-speed gear should be regarded as primarily an economiser of effort rather than as an increaser of velocity.

Want of space forbids the discussion of many interesting points about change gears that have been raised in cycling journals. For the same reason the writer has omitted detailed reference to the Garrard, Sunbeam, Protean, Collier, and other gears in more or less common use.

In conclusion, he desires to thank the makers of the devices here described for the loan of machines fitted with the gears, and also of séparate gears for dissection, and of diagrams for reproduction. In addition, he is indebted for the courtesy with which his enquiries have been answered.

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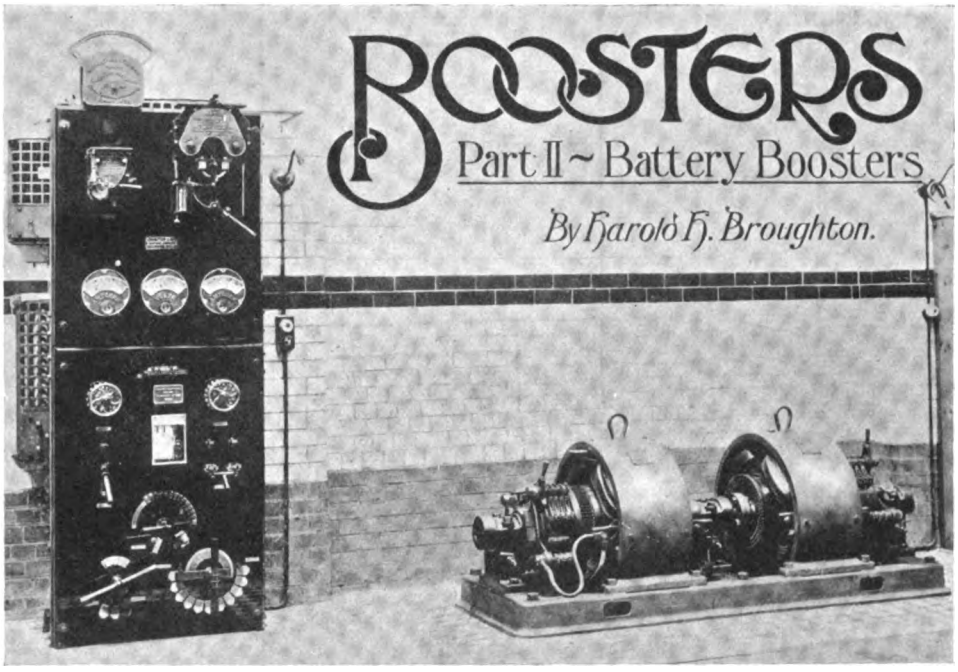

BOOSTERS

Part II ~ Battery Boosters

By Harold H. Broughton.

BATTERY boosters may be divided into two classes:—

(*a*) Irreversible Boosters.

(*b*) Reversible Boosters.

Irreversible Boosters.—When a battery is installed to supply current to the external circuit during periods of light loads, or when the main generators are standing, it is customary to charge the battery from the main 'bus bars, the extra voltage required being obtained from a booster placed in circuit with the battery. The advantages of this arrangement are that the main generators need not be called upon to generate a higher voltage than is required on the main 'bus bars; there is no need to keep a special machine for the higher voltage; and further, the external circuit can be fed, and the battery charged, at one and the same time. There are several ways of combining a booster with a battery—the machines may be either shunt, series, or compound wound. In the shunt-wound booster, the armature is driven at constant speed, and is in series with the battery across the 'bus bars; the shunt coil is connected across the armature or 'bus bars, with or without reversing switch (see Fig. 13, *a*, *b* and *c*). Where the shunt is across the armature, the excitation depends upon the variable P.D. at the booster terminals, and this varies the shunt current. In the second case, where the shunt is connected to the 'bus bars, the voltage across which is constant, the excitation has but one value, and the boost is constant. To charge the battery, the shunt coils must be connected so that the booster voltage is added to that of the 'bus bars, and for discharging the connections must be reversed. The action during discharging or charging is fairly automatic, but the necessity of providing a reversing switch is a serious disadvantage.

In series-wound boosters (Fig. 14), the battery, booster armature, and field are connected in series. The arrangement requires no reversing switch, since the sign of the induced E.M.F. changes with the direction of the current through the field, and the boost varies with the current by an amount depending upon the characteristic of the machine, being least when most is required.

Compound-wound boosters (Fig. 15) afford a little closer regulation than either of the above. The shunt winding, which has to be provided with a reversing switch, may be connected in either of the ways mentioned above, and the series coil connected in the armature or feeder circuit.

These machines are little used except in small installations, and as we have yet the important second class to consider, it will be sufficient, for the present, if we describe one form only, which has the advantage of simplicity, and requires only one regulating

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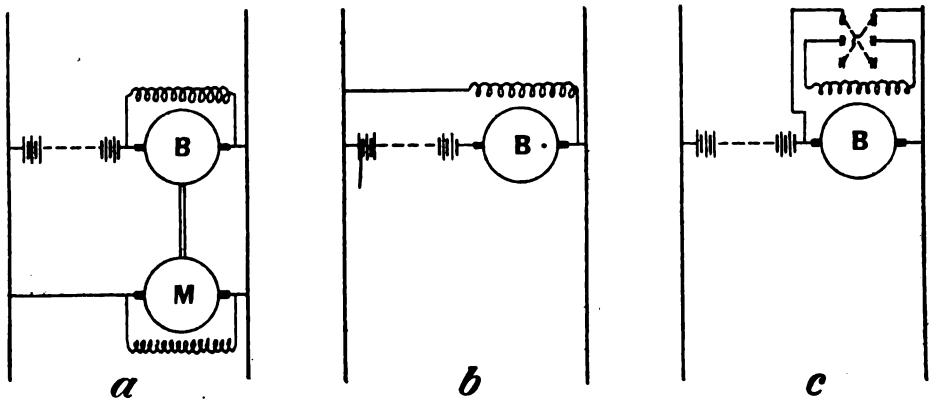

FIG. 13.—THREE TYPICAL SHUNT-WOUND BATTERY BOOSTERS.

switch—a distinct advantage for small installations where the staff very often consists of one unskilled man.

The arrangement is shown diagrammatically in Fig. 16; G is the main generator; BB are the 'bus bars; M is a shunt motor coupled mechanically to the booster B. The speed of M, and therefore the voltage of B, is controlled by means of the regulator MR, which also serves the purpose of starter for M. The field of the booster is shunt-wound, and is provided with a regulator, which allows of wide variation of the voltage across the booster armature. The practice of putting the armature windings of M and B on a common core and using a single field, has met with little favour; most engineers prefer two machines coupled together. One terminal of the battery is joined up to the 'bus bars through an ammeter A, which shows the current passing, and also whether the battery is charging or discharging; the cells at the other end of the battery are connected to the booster through the regulating switch RS, and the change-over switch CS either puts the booster in circuit with the battery, or cuts out the booster and puts the battery directly on the line; when in the off-position, both booster and battery are out of circuit. To charge the battery, the change-over switch is put in the off-position, and all the cells put in circuit by means of RS; the booster field is put directly across the 'bus bars by cutting out SR. MB is next started up to full speed so as to allow B to generate at full voltage, and the booster is then put in circuit with the battery by throwing over switch CS into position 1, and the charging current indicated on A is brought to its proper value by regulating the speed of M, or by altering the excitation of B. When the battery is charged, the shunt regulator of B and the regulating switch are adjusted until A indicates no current: the battery circuit is then opened by means of CS, and the motor stopped. The battery voltage, as indicated by V, can be adjusted by means of RS to the required value, and the battery switched directly on to the 'bus bars at CS, when G may be stopped.

*Automatic Reversible Boosters.**—In all traction stations it is no uncommon thing for "peaks" of two and a half times the mean current to occur several times an hour; the load varying between zero and 450 K.W., the average output being about 150 K.W. (*see* Fig. 17).

It is obvious that a battery alone is of little use in such cases. When a discharge is taken out of it, its voltage will fall, and the discharge will cease; and when a charge is put into it, its voltage will rise, and the charge will cease. To overcome these difficulties, the Automatic Reversible Booster has been designed; for manifestly

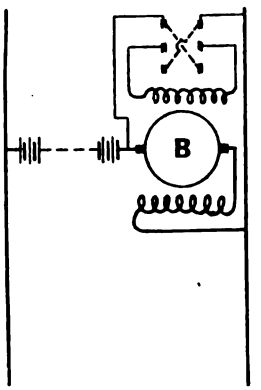

FIG. 15.—COMPOUND-WOUND BATTERY BOOSTER.

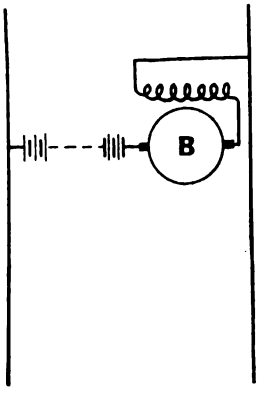

FIG. 14.—SERIES-WOUND BATTERY BOOSTER.

* See Journal of the Institute of Electrical Engineers, Vol. XXX., p. 1040, 1901, for a full discussion.

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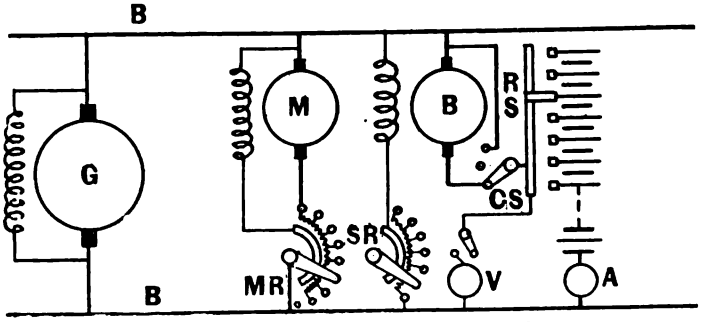

FIG. 16.—METHOD OF USING IRREVERSIBLE BOOSTER.

where a battery is used to equalise the changes of load, the booster *must be automatically reversible.* These machines are chiefly used for working on a power system with a battery in parallel with the generators, the object being to keep the load on the dynamos practically constant, the battery discharging when the load rises above the normal, and charging when it becomes less than the normal. Briefly stated, the advantages claimed for the system are :—

1. The saving in initial capital outlay.
2. Constant operation of plant at full load or maximum efficiency. *
3. Saving in wages at the generating station, through shortening the running hours.

* Under certain conditions often met with in central stations it is altogether impracticable to operate the plant at full load continuously. See later.

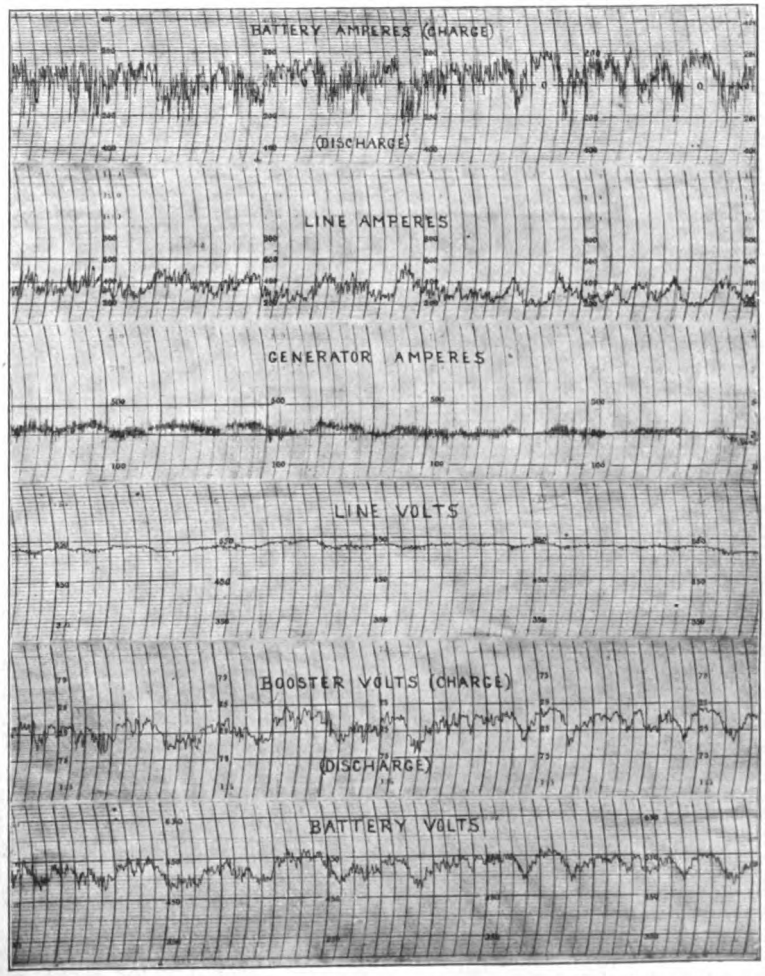

FIG. 17.—RECORD TAKEN FROM TRACTION LOAD WITH E.P.S. BATTERIES IN CONJUNCTION WITH ORDINARY DIFFERENTIAL BOOSTER.

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4. Means of charging the battery while operating the load.

5. Automatic control of the battery.

In order to get the quick reversal necessary, as little iron as is compatible with efficiency should be used in the magnetic circuit, and both armature and field magnets should be finely laminated; a little care in the design will save endless trouble afterwards.

We shall describe the machines most commonly used in this country, each of which has had a fair trial, and gives every satisfaction.

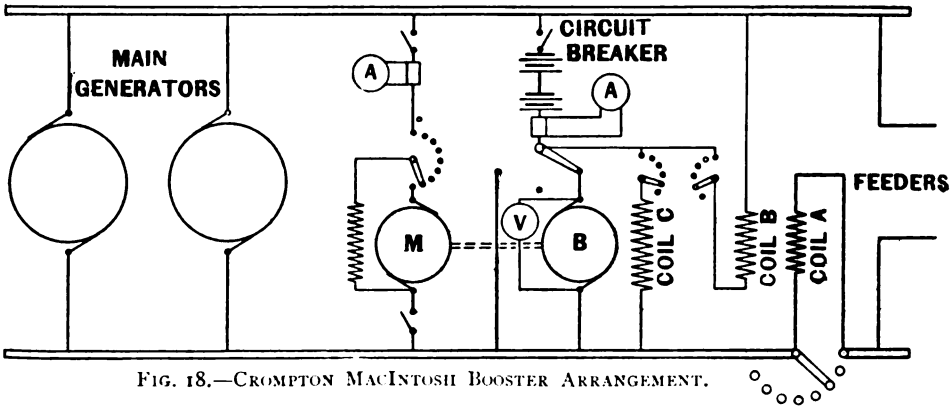

FIG. 18.—CROMPTON MACINTOSH BOOSTER ARRANGEMENT.

Crompton MacIntosh Booster. — This machine was one of the first to be introduced for running a battery in parallel with the main generators, and is generally known as the "Chelmsford Booster." The booster is connected in series with the battery; its field, which varies and reverses automatically, is a function of the feeder load and of the battery volts.

In this way, the 'bus bar pressure, which is equal to the battery volts *plus* or *minus* the booster volts, is kept constant. When the feeder current rises above the normal, the booster draws a corresponding current out of the battery; and, when the feeder current falls below the normal, the booster forces the surplus current into the battery, always keeping the generators at the same load, and preventing the 'bus bar volts from varying.

Fig. 18 shows the main generators, the battery, and the booster driven by a motor. The booster field is excited by the coil C, and the differential winding A and B.

When the battery volts are equal to the 'bus bar volts, there is no current in coil C, and it has no effect. When the battery pressure is lower than that of the 'bus bars, a current flows in coil C in one direction, and when the battery pressure is higher, in the other direction. Thus, for every volt fall of the battery, the booster gives one volt positive, and for every volt rise of the battery, the booster gives one volt negative.

In order that any considerable current may pass out of, or into, the battery, it is necessary to provide further excitation to provide for the armature reaction. This gives a means of regulating the amount of current that shall pass. The differential coils A and B accomplish this. Coil A carries the whole (or a definite adjusted proportion) of the feeder current; coil B is a shunt coil which opposes A.

To take an example: Suppose the 'bus bar voltage is 500, and the mean load is 400 amperes, and that the generator is to be kept constant at this.

When the feeder current is 400 amperes, coil A will exactly equal coil B, and the differential excitation will be nil.

1. Now suppose the feeder current rises to 900 amperes, 500 amperes are required from the battery. Coil A will overpower coil B, and will produce a discharge voltage just sufficient to compensate for the armature reaction of 500 amperes. A discharge current of that amount, and no more, will therefore flow. This will cause the battery to fall to about 450 volts, but the result of this is to make a current flow in coil C, proportional to the difference between the 'bus bar and the battery voltages; and the excitation of coil C under these conditions will give exactly 50 volts positive to the booster, so that the battery and the booster volts will be 450+50 = 500 = the 'bus bar volts.

As the discharge continues, the battery will fall still lower, but for every volt it falls, coil C will add a volt to the booster.

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2. Suppose, next, that the feeder current drops from 900 to 100 amperes. It is desired to still keep the generator at 400 amperes, therefore 300 amperes must go into the battery. With a feeder current of 100 amperes, coil A will be only one quarter as powerful as coil B, and the differential excitation will be in the opposite direction from what it was in the first case.

It will, in fact, be just strong enough to compensate for the armature reaction of a charging current of 300 amperes. The battery voltage will quickly rise from below 460 to about 540, and coil C will reverse, giving the booster a voltage of − 40. The battery and booster will therefore be 540 − 40 = 500, the 'bus bar voltage.

These two cases show how the generator may be kept constantly at full load, and how all variations are taken up solely by the battery.

When it is desired to run the station on the battery alone, without the assistance of a generator, coil B is cut out. This coil can be varied in strength, by means of a rheostat, according to the size and number of the generators which are running.

The operation of switching the battery and booster on to the lines is as follows:—Put the three-way switch on the middle stud, and put the battery circuit breaker in. The battery will probably stand at quite a different voltage from the 'bus bars. Now run up the booster (which is on open circuit). Cut out coils A and B, but leave coil C in. The booster will be found to give a voltage exactly equal to the difference between the battery and the 'bus bars, and the three-way switch may therefore be thrown on to the booster stud, completing the battery circuit without a spark. Now put coils A and B in, and the switching in is complete.

In some tramway stations it is desired to make the 'bus bar voltage rise and fall in proportion to the load, so as to compensate for the drop in the outgoing feeders. It is evident that this cannot be accomplished by over-compounding the main generators, the current from which being kept constant whatever may be the load.

Crompton's method is shown in Fig. 19. The arrangement is similar to their booster (Fig. 18), the only difference being the equaliser bar introduced in such a way that the *battery* current as well as the generator current flows through the series winding of the generator. This causes the 'bus bar volts to rise in proportion to the total outgoing current, and the battery and booster volts will still be equal to the 'bus bar volts at any moment, no matter how the latter may charge.

This booster enables both the current and the voltage to be entirely under control.

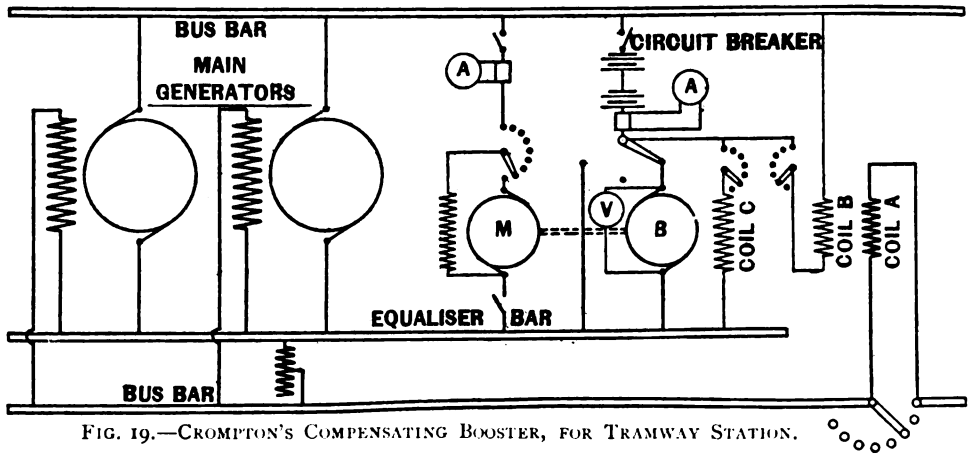

FIG. 19.—CROMPTON'S COMPENSATING BOOSTER, FOR TRAMWAY STATION.

The illustration at the head of this article shows a Crompton MacIntosh booster, together with the necessary switch-gear, the wiring for which will readily be understood by comparing with Fig. 18.

The Highfield Automatic Reversible Booster.—The chief feature of this booster is that it functions with balanced voltages instead of balanced currents. The combination consists of three machines—booster, motor, and exciter. As will be seen from Fig. 20, the booster field has three windings—a shunt coil and two series coils. The shunt coil A is capable of giving a maximum boost, on charge, of 120 volts for a 500–550 volt machine. The series coil B, which the makers term the "diverter coil," carries a

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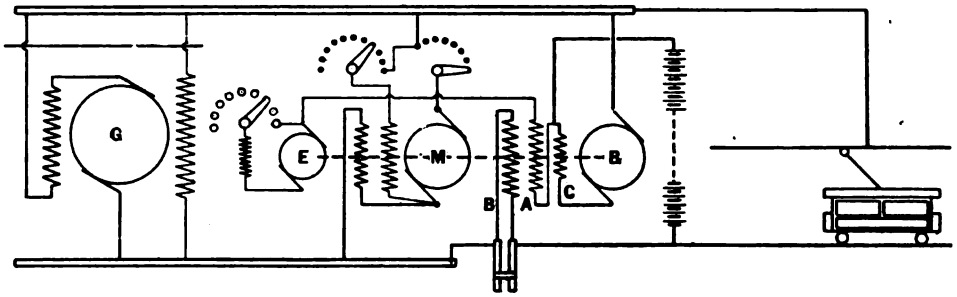

FIG. 20.—HIGHFIELD AUTOMATIC REVERSIBLE BOOSTER.

portion of the whole output of the station, and gives a small boost (the maximum being 5 per cent. of the line pressure) in the discharge direction, and serves to keep up the pressure during periods of maximum fluctuations, and to account for the drop in the leads and feeders. The third coil C consists of two or three turns only in series with the armature, and overcomes the reaction of the latter. The exciter is arranged to give any pressure between 500 and 550 volts, and one pole is connected through the booster shunt coil A to the battery terminal of like polarity, and the other pole to the other battery terminal. Thus the exciter is connected through the booster shunt, across, and in opposition to, the battery. It will thus be seen that so long as the voltage across the battery is equal to the voltage of the exciter, the two pressures will balance each other, and no current will flow through the booster shunt field, and there will be no boost; but as soon as the battery volts drop on discharge, the exciter will send a current through the booster field, and the resulting voltage across the booster armature will be exactly equivalent to the drop across the battery terminals, keeping the voltage of the combination constant. Thus, supposing the exciter is set to give 550 volts, should the battery fall to 500 volts, the boost in the discharge direction will be 50 volts. Records show that the line voltage can be maintained within 1 per cent., notwithstanding peaks of 350 amperes. When the voltage of the battery rises, a current flows in the booster shunt field, proportional to the difference between the battery voltage and that of the exciter, which is motored; the booster armature then gives a pressure equal to the rise of battery pressure. Speaking generally, the exciter runs as a motor when charging, and as a generator when discharging: but occasionally, when the cells are low, charging begins at a lower pressure than the line voltage, and under these conditions the booster runs as a motor, and the motor as a generator, returning energy to the line. Also when the battery is fully charged, the pressure is generally greater than the line pressure; should the battery in this condition be called on to discharge, the booster opposes this discharge, and is motored; the motor then runs as a generator, and returns energy to the line. Some recent tests show that this arrangement brings about a saving of some 30 per cent. in the amount of current required to run the motor.

(To be continued.)

A Phospho-Organic Acid in Wheat Bran

PRACTICALLY all the soluble phosphorus containing constituent of wheat bran is a magnesium-calcium-potassium salt of an organic phosphorus acid of the formula $C_2H_8P_2O_9$, which is probably identical with Posternak's anhydro - oxymethylene diphosphoric acid. The alkali salts of this acid are freely soluble, the calcium copper salts are slightly soluble, and the barium and strontium salts are but sparingly soluble in water. This acid and its salts seem to be widely distributed in the vegetable kingdom; they have been found in the seeds of the red fir, peas, beans and lupines, and in the potato and other tubers and bulbs. (A. J. Patten and E. B. Hart: Bull. No. 250, New York Agricultural Experimenting Station, Geneva, N.A.)

S. Posternak finds that all vegetable reserve material destined for future nourishment of the embryo contains an organic phosphorus compound which has not hitherto been described, and which he names "Phytin." Its empirical formula is $C_2H_8P_2O_9$; it has the constitution of an anhydro - oxymethylene - diphosphoric acid. (*Journ. Pharm. Chim.* [6], 18, 543.)

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LEADLESS DECORATIVE TILES, FAIENCE AND MOSAIC.*

By WILTON P. RIX.

BY the publication of this exhaustive work, the author is to be congratulated on having conferred an important benefit on the community at large.

It is true that the subject of leadless glazes in its technical aspect is one which has called forth the most diverse opinions from those who might be deemed competent judges. To the lay observer and the retail consumer, however, all the practical difficulties which beset the manufacturer in abandoning the use of plumbic glazes are not likely to be apparent.

The broad consideration of general excellence at the lowest price, by whatever means obtained, naturally commends itself to the retail purchaser. The whole contention for and against the use of leadless glazes must finally centre around this issue.

But the insidious evils arising to the worker from the use of glazes containing free lead, occasionally ending in paralysis, blindness, or death, cannot possibly be ignored, and the saving to the consumer at such sacrifice is wholly unjustifiable if it can be avoided.

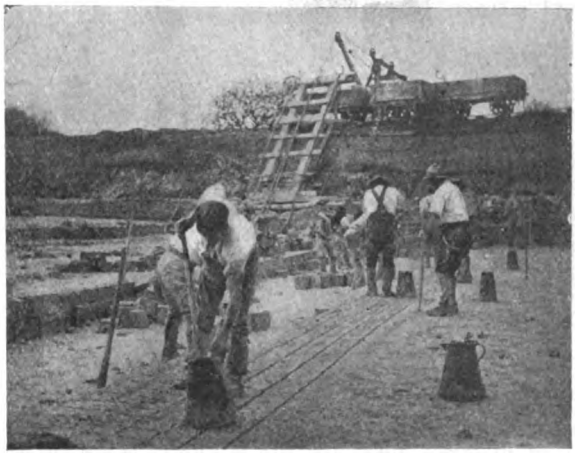
It has been contended by the majority of manufacturers that the adoption of any of the formulæ for lead-free glazes at present known was impossible, owing to the increase of defective ware produced and the inferior brilliancy of the glaze texture.

To the solution of this problem the author has devoted many years of patient research, and the present volume now issued gives the result of his efforts, so far as it relates to the more fusible glazes required for decorative faience and architectural tiles.

Mr. Furnival has, however, wisely extended the scope of his book to include much that will be interesting to the general reader, a considerable portion of the work being devoted to a historical review of ancient tile work, and the rise of the modern industry.

In dealing with this portion of the subject, the author has been most fortunate in securing the assistance of such well-known authorities as Dr. Stephen W. Bushell, M.D., C.M.G., who contributes notes on Chinese Faience; C. Stanley Clarke, Esq., who writes on Indian Tile Decoration; and J. H. Marshall, Esq., who has added some pages on Tile Decoration in Punjab and Bengal. The whole work is profusely illustrated with subjects which not only embellish the work, but are also distinctly relevant to the matter in hand.

In the more practical sections of the book the reader is furnished with chapters treating of every branch of the manufacture, these being largely composed of quotations from leading authorities in their respective departments.



OPEN-PIT WORKING, NORTH DEVON.

The writer, by adopting this method, has no doubt furnished a useful encyclopædia of the statements of scientific and practical men. Its value, however, would be greatly increased by a less diffuse treatment or a more copious index. The uninitiated student will also, no doubt, find some embarrassment in discriminating between the statements and opinions quoted from so many sources upon the same subject, some of which may have much greater weight of authority than others, and upon this point the writer is in most cases silent.

* LEADLESS DECORATIVE TILES, FAIENCE AND MOSAIC. By W. J. Furnival; pp. xxiv.+852, with 329 diagrams and 37 plates. Published by the Author at Stone, Staffordshire; 1904.

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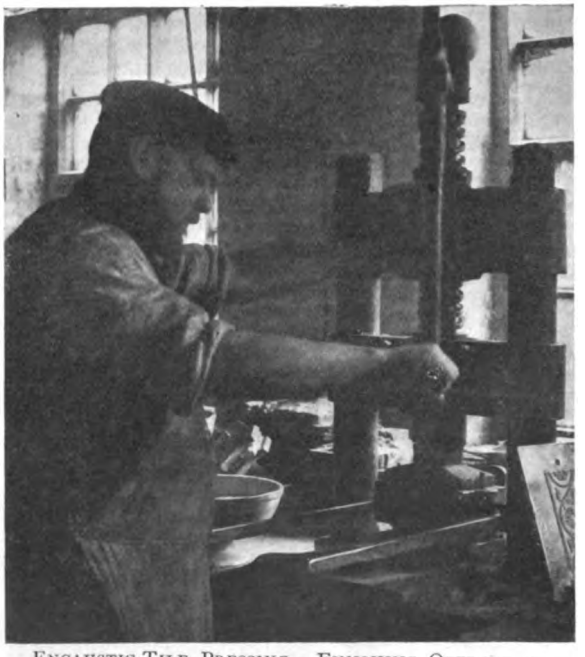
The chapter on sources and preparation of materials is very ample in its details. The student will find here much interesting matter having reference to the occurrence of these materials in all parts, including America and the Continent. Much of the information is made available from sources not usually accessible to the general reader, and is for this reason all the more valuable. More especially is the study of this section necessary, as the manufacture of pottery becomes extended to new countries and districts where materials are available only in their raw state, and cannot be obtained ready prepared as in this country.



ENCAUSTIC-TILE PRESSING: FINISHING OPERATION.

Among other matters, the effect of fine or coarse grinding of materials, and also of wet, compared with dry grinding, is fully dealt with in extracts from the numerous statements of experts. The author points out that "even as far back as the time of Josiah Wedgwood the effect of fineness of grinding potters' materials had been an object of concern, inquiry, and experiment."

The conclusions arrived at by tests, quoted from the North Stafford Ceramic Society's transactions, are given as under:—

(1). The flint in an earthenware body causes the contraction to vary inversely as the diameter of its grains.

(2). The porosity varies directly with the diameter to ·05 mm.; below that it varies inversely as the diameter.

(3). The effect on the glaze is that the tendency to craze increases with the size of the grains of flint.

(4). The stone in an earthenware body causes the contraction to vary inversely as the diameter of its grains.

(5). The porosity varies directly as the size of grain.

(6). The effect on the glaze does not tend to crazing, but the eggshelly effect diminishes with the size of grain; but when the stone is less than —029 mm. diameter, it causes a blistering of the body when glazed.

(7). The size of grain in the body does not produce "spit-out" ware.

The technical reader will find much valuable information in the section devoted to ceramic pyrometry, which treats very fully of the subject, and includes illustrations and details of all the latest appliances.

The criticisms on the limitations of the Wedgwood Pyrometer are especially useful, showing as they do the difficulty of attaining practical and accurate indications of the true character of the firing process.

The quotations are worthy of the careful attention of the student, and form a very useful epitome of the subject.

Thus the author quotes the very important point noted by Mr. Watkin, that "Pottery firing is not conducted for the estimation of temperature, but for the purpose of increasing the density and vitreousness of ware," and further, "Contraction, density, and vitrescence, which always accompany the firing of pottery, are not necessarily produced at any given degree of heat. The contraction and increase of density as the result of firing are not always strictly proportionate to the degree of heat to which such bodies have been exposed."

The use and composition of Seger Cones is also fully described; and the criticisms of Professors Orton (junior), Binns, and Langenbeck, on the construction of the formulæ for these cones, are also added.

There appears to be little doubt that certain of these cones are open to improvement as regards their composition, and the suggestions of Langenbeck and Binns are quoted, practical mixtures being stated in full.

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The pyroscopes of Holdcroft and the heat recorders of Watkin are also efficiently explained.

The remaining portion of the chapter consists of an extended notice of the various forms of thermo-electro pyrometers, which is admirably illustrated.

In reply to an interesting enquiry made as to "the possibility of ascertaining the temperature existing in the interior of potters' kilns when under fire, by means of wireless electric currents traversing the kiln between electrodes fixed on either side outside the kiln," the following reply from Sir Oliver Lodge is quoted, which is deserving of notice :—

"I think it is quite possible that something like a thermometric arrangement across the hot space inside a potter's kiln could be arranged without any interior conductors. I assume that carbons might be passed through the walls into the interior. The plan would be to measure the conductivity of the air inside; it is bound to depend on temperature, but it would not discriminate local from average temperature. I do not say that it would be automatic, but I think it might be troublesome. Moreover, a great deal of work on the subject would be necessary in order to make it possible."

Chapters VI. and VII. are devoted to floor tiles, and in dealing with the firing of these goods, extracts from a paper by Professor Orton, junior, are most judiciously selected.

Thus in reference to the dehydration period this is stated to be divided into :—

"(*a*) Expulsion of hygroscopic water from the clay.

"(*b*) Combustion of carbonaceous matter.

"(*c*) Distillation of S from pyrites, leaving FeS.

"(*d*) Dehydration of kaolinite, ferric hydroxide, and other hydrous minerals.

"(*e*) Decarbonisation of carbonate minerals."

With reference to the *oxidation period*, Professor Orton tells us that it has been his experience "that the difficulties and losses in the burning of crude clay-wares are more largely referable to mismanagement of this phase of the burning than to any other."

In reference to vitrification, the following extract from Professor Orton's paper is also worthy of note :—

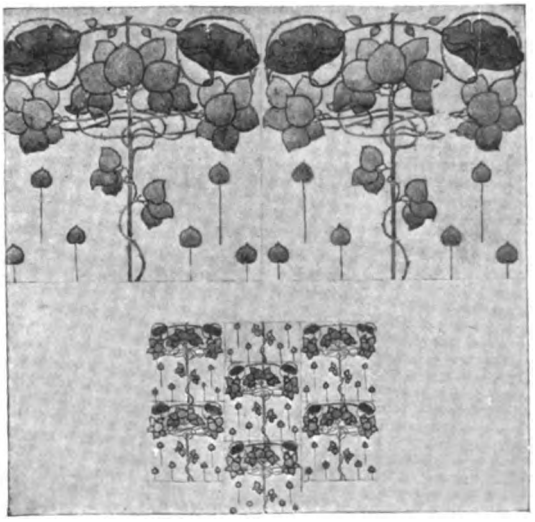
"Complete vitrification means that stage of a clay-burn where it becomes densest and strongest. All clays pass in burning through a series of stages, and are progressively harder, stronger, and denser up to a maximum; after that they begin to fall off."

Under this section the author also treats of firing with natural gas, as adopted in America. Considerable space is also devoted to the discussion of the possibility of adopting Mond gas for burning pottery ware.

It may be noted, however, that no practical suggestions or statistics appear to be available for the guidance of the potter, and the matters seem hardly to have passed the initial stage.

While the ordinary reader will no doubt turn with interest to the historical portions of the work, the potter will naturally look for new and practical information and the result of fresh research. In both these directions the technical reader will not find himself disappointed. Though the space occupied represents but a very small part of the whole, the proportion of labour entailed in verifying the same is by no means so limited.

Mr. Furnival has given a considerable series of formulæ for floor tile bodies, and also of those for glazed tiles, decorative slips, parian bodies, and vitreous stone bodies. Many of these will doubtless prove valuable to the potter seeking for new recipes as a basis for improving his manufacture.



Design for Tile. By Harry Allen (Burslem).

The author, however, gives no indication as to whether these formulæ are the result of

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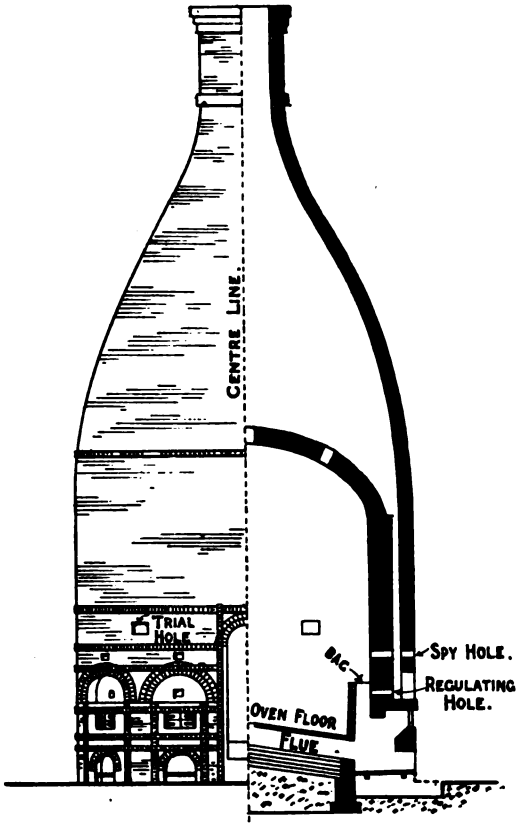
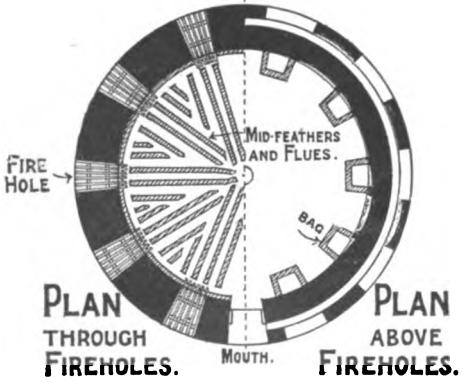
his own research, or whether they have been verified by him under commercial conditions.

The addition of a note stating the most suitable temperature and the shrinkage of the bodies, would greatly enhance their value in practical work.



ELEVATION. SECTION.

FEET 0 1 2 3 4 5 6 7 8 9 10



GLOST OVEN.

W. CAMPBELL. ARCHITECT, HANLEY.

A series of twenty-four underglaze colours is also given which, it may be presumed, have been found specially suited for use with leadless glazes, though this is not stated.

Among these the absence of yellow is noticeable, the writer merely "suggesting" the use of yellow rutile diluted with tile body.

The use of copper is also entirely eliminated.

In Chapter XI. the reader will find the *raison d'être* of the whole work, the subject being "Leadless Glazes and Art Enamels."

The special qualities demanded in such glazes differ somewhat from those required for domestic earthenware and china. For faience especially, complete fusibility at a low heat is essential, while the capacity to produce brilliant and rich tones of colour when fritted with metallic oxides is equally needful.

As to the former point, the reader is furnished with a table of temperatures at which the frit mixtures proposed will fuse, showing a range from 700° C. to 900° C.

On the second point of colour and texture, the author says:—

"Respecting the particular series of recipes for such glazes published in the following pages, it is not claimed that they will under every set of conditions, favourable or adverse, yield products superior to those on the market, or beyond criticism. What is expected of them, as the result of many experiments, is that they will yield, to the exercise of equal skill and favour, results equal to the average of contemporary products in lead glazes for like purposes, except in the case of red and French-pink glazes."

In reference to texture, the author here quotes a very significant passage from Dr. Seger, of Berlin, who says:—

"The lead oxide, without doubt, is the metallic oxide most suited for the production of glazes. Its solubility in water, which permits of its use in the free condition; the instability of its compounds, and especially of the carbonates and sulphates; its fusibility and the fusibility of its silicates . . . . are properties which no other metallic oxide can attain; these are all reasons why lead oxide is so suitable as a glaze material.

"At this point I wish to call attention to the fact that the pottery coated with a glaze free from lead assumes a different character entirely; it loses the gloss peculiar to lead

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glazes, and assumes more the character of the porcelain glazes. In how far this may injure or benefit the industry commercially, I shall not venture to say; but I believe that this question will not offer an obstacle to the use of glazes free from lead."

Criticising these statements, Mr. Furnival says:—

"As to comparative glossiness, however, apart from shimmer, the writer's experience shows that certain leadless glazes, dipped on the same pieces of ware and burned in the same sagger with lead glazes, yield results equal to lead glazes, and sometimes more glossy."

The author next proceeds to deal exhaustively with the influence of the various fluxes capable of use as alternatives to lead. He also adds a carefully written note on comparative costs, in connection with which he states:—

"But to make a just comparison, it is necessary to take into consideration the relative covering power, because, by reason of the lower specific gravity of leadless glazes, it has been found in practice that weight for weight they cover considerably more ware than lead glazes."

More than thirty pages are allotted to a complete series of formulæ for colourless and coloured glazes and frits. The colourless glazes are thirteen in number, one of the noticeable features being the small contents of unfritted ingredients which vary from 5 to 10 per cent. From these are constructed formulæ for coloured glazes, some 150 in number, producing more than 50 tints. Respecting these, the writer states:—

"The following recipes include a considerable assortment of various tints and hues, which may be increased by mixing the several glazes together in various proportions, regard being paid to those glazes that agree well when mixed together."

So far as can be seen, the heats at which these colours mature appear to give sufficient margin for producing glazes of suitable fluidity. It is, however, unfortunate that Mr. Furnival omits to state the actual temperature at which the respective glazes will fire to the best advantage.

This, however, is a point that can be easily ascertained by the practical potter, who will doubtless also desire to find out whether these glazes are free from the usual objection of sluggish fluidity and absence of readiness to heal slight defects left in dipping, to which hitherto leadless glazes have been peculiarly liable.

If this should be the case, the book will not only prove a valuable addition to ceramic literature, but also a boon to the practical potter, by removing the stigma which has hitherto attached to the deleterious nature of the potter's art.

ACTION OF WATER ON SILICON.

A DISTINCT amount of hydrated silicon is formed after from 6—12 hours, when silicium is left in contact with water at 95° in a glass tube. If a platinum vessel be used, or if faintly acid water be used in a glass vessel, no reaction occurs. Water distilled from platinum vessels has no action on silicium placed in a small vessel made of fused silica. An infinitesimal trace of alkali is necessary to start the reaction in a glass vessel. The small amount of alkaline silicate formed is dissolved by the water, and the action becomes progressive. The necessary alkali is dissolved by the water from the glass.

$$Si + 2NaOH + H_2O = SiO_2Na_2 + 2H_2$$

Crystalline silicon dissolves in pure silver better than in zinc or lead, and after crystallising from its solution in silver is soluble in hydrofluoric acid. The silicon obtained hitherto has been insoluble in this acid. (H. Moissan and F. Siemens. Comptes Rend. 138, 939, 1299.)

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART VI.—MAGNETISATION.

By EDWIN EDSER, A.R.C.Sc.

IN the February number of TECHNICS it was proved that, within a long solenoid wound with n_1 turns of wire per centimeter length, the magnetic field (force per unit N pole) is equal to $4\pi C n_1$, where C is the c.g.s. value of the current flowing along the wire. If a rod of iron or other magnetic material is placed within the solenoid, this will become magnetised; consequently $4\pi C n_1 = H$ is called the *magnetising force* to which the iron is subjected.

If the rod of iron is very long in comparison with its sectional area, the lines of force, after leaving its N pole, will diverge very quickly, so that over any chosen path from the N to the S pole the average force on a unit pole will be very small; the value of this average force will diminish as the length of the rod increases, and finally for a rod of infinite length the force will be equal to zero. In general we may neglect the average force which acts on a unit pole as it is carried from the N to the S pole of a magnetised rod, if the length is more than 500 times the diameter of the rod; and, therefore, in carrying a unit pole from the S to the N pole inside the rod, and then from the N back to the S pole outside the rod, work will be done only while the unit pole is within the rod. If the number of lines of force per square centimeter within the rod is equal to B, then the force acting on the unit pole within the rod is equal to (B/μ), and the work done in passing from the S to the N pole within the rod is equal to $(B/\mu) \times l$ ergs, where l is the length of the rod in centimeters. Let us suppose that the path from the N back to the S pole is chosen so that it goes straight from the N pole through the windings in a direction perpendicular to the axis of the solenoid, then along any arbitrary curve, and finally back to the S pole in a direction perpendicular to the axis of the solenoid. In this case, the path will embrace those turns wound on a length l of the solenoid, *i.e.*, $l n_1$ turns; consequently the work done in traversing the whole of the closed path from the S to the N pole inside the rod, and back from the N to the S pole outside the rod, will be equal to 4π times the current multiplied by the number of turns of wire embraced, or $4\pi C n_1 l = H l$ ergs. Hence

$$\frac{B l}{\mu} = H l$$

$$\text{and } B = \mu H.$$

It thus appears that the lines of force per square centimeter within the iron are μ times as numerous as if the iron were absent. Within the iron the force acting on a unit N pole is the same as if the iron were absent; but if a narrow transverse cut were made across the rod, the force acting on a unit N pole placed in this cut would be equal to $B = \mu H$, since the lines of force cross the slit in air. Let a rod be magnetised by a given current flowing round a solenoid; then it is easy, by the magnetometer method, to determine the pole strength of the rod. If this is done, and we can find the connection between B and the pole strength, we can calculate the value of B. The value of the magnetising force H being known in terms of the magnetising current C and the number of turns per centimeter wound on the solenoid, the value of (B/H), or μ, can be found.

The number of lines of force per square centimeter within the iron (*i.e.*, B) must be equal to the number of lines of force per square centimeter due to the current flowing round the solenoid (*i.e.*, H) *plus* the number of additional lines of force per square centimeter due to the iron itself. Let us suppose that, without altering the number or distribution of the lines due to the iron itself, we remove those due to the solenoid; and that in this case the pole strength of the magnetised iron rod is equal to m. Then we know that $4\pi m$ lines leave the N pole, and the same number of lines enter the S pole of the rod; according to supposition, these lines proceed straight along the rod internally, so that if a is the sectional area of the rod, $(4\pi m/a)$ will be the number of lines of force per square centimeter within it.

Thus $$B = H + 4\pi \frac{m}{a} \quad . \quad . \quad . \quad . \quad (1)$$

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The quantity m/a is called the *intensity of magnetisation* of the rod, and is generally denoted by I. Thus I is the pole strength per square centimeter sectional area of the rod.

If the length of the rod is l, this will be approximately equal to the distance between the poles of the magnetised rod, and we therefore have

$$I = \frac{m\,l}{l\,a} = \frac{M}{v}$$

where M is the magnetic moment, and v the volume of the rod. Thus I, the intensity of magnetisation of the rod, is also equal to the magnetic moment per unit volume of the rod. From (1)

$$B = H + 4\pi I$$

$$\therefore \mu = \frac{B}{H} = 1 + 4\pi\frac{I}{H} \quad . (2)$$

The quantity (I/H) is called the *magnetic susceptibility* of the substance of which the rod is composed, and is usually denoted by the symbol κ. From (2)

$$\mu = 1 + 4\pi\kappa.$$

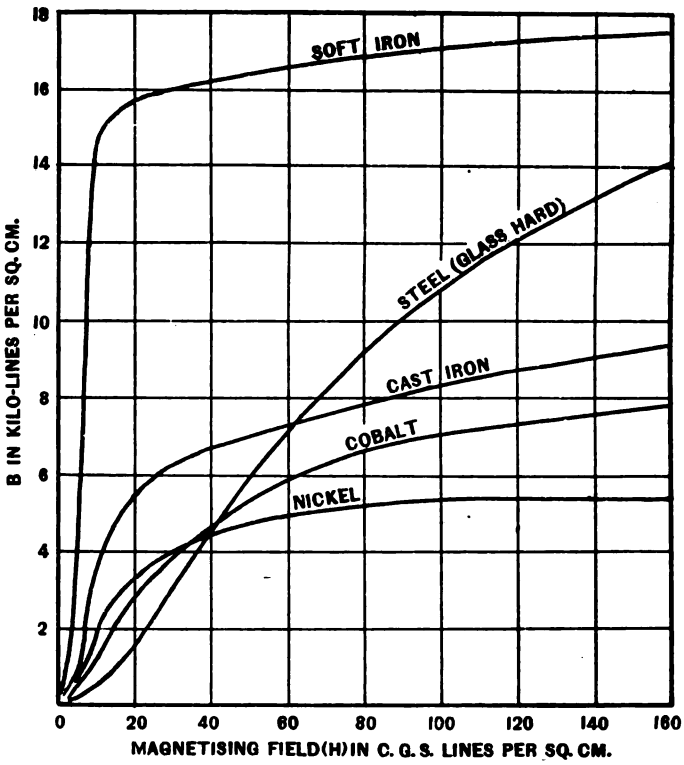

FIG. 1.—MAGNETISATION CURVES FOR SOFT IRON, STEEL, CAST IRON, NICKEL AND COBALT.

The above reasoning shows that by determining the pole strength or magnetic moment of a given rod when placed in a known magnetising field, the value of B within the rod can be found, and from this we can determine the permeability μ of the rod. The curves in Fig. 1 give general values of B for different values of H, for soft iron, glass-hard steel, cast iron, nickel and cobalt. From Fig. 1 it will be seen that μ is not a constant for any of these substances: as H increases, the ratio of B to H at first increases, then reaches a maximum value, and finally decreases.

We must now consider the variation of B with increasing values of H in greater detail. It has been found that if a rod of unmagnetised iron is subjected to a very small magnetising force H (less than about 0·04 c.g.s. units for soft iron), B is proportional to H; so that if H is plotted horizontally and B vertically, we obtain a straight line O C (Fig. 2). When H reaches a certain value, B suddenly commences to increase much more quickly than H, so that the next part of the magnetisation curve can be represented by the line C D. After the point D on the curve has been reached, the value of B ceases to increase so quickly, and the remainder of the curve is the straight line D E. At the point D the iron is said to be *saturated*; from this point onward an increase in H leads to no increase in the number of lines of force due merely to the iron, the only increase in B being due to the increase in the lines of the magnetising field. In practice the angles at C and D are found to be rounded off as shown in the full line curve.

When the iron has been magnetised so that B reaches the point E (Fig. 2), a gradual diminution in H causes B to follow the curve E F; consequently when the magnetising field has been entirely removed the magnetism has not sunk to its original zero value, but is such that B still retains the value O F. The value of O F, which is a measure of the so-called residual magnetism, varies with different samples of iron: it is small for soft iron, and sinks to zero when this is subjected to vibration; on the other hand, it is fairly large for hard steel. If the magnetising field, after being reduced to zero, is gradually increased in a reverse direction, the value of B follows a curve such as F G (Fig. 2); thus

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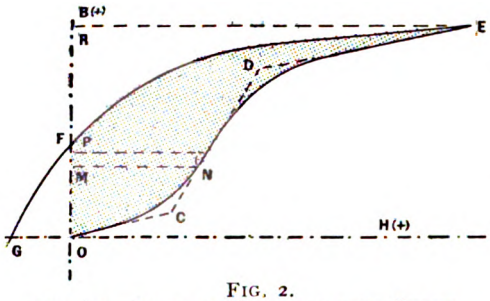

FIG. 2.
GENERAL FORM OF MAGNETISATION CURVE.

a reverse field equal to O G is required to destroy the magnetism remaining to the rod when the original magnetising field sank to zero. O G is termed the *coercive force*; it is very small for soft iron, but larger for steel, especially when this has been hardened.

If the reversed field is now numerically increased, B becomes negative, and follows the curve G K (Fig. 3). On gradually diminishing H until it falls to zero, B follows the curve K L, and a subsequent increase of H in the positive direction causes the curve to run into the original curve O C D E at some point between C and D.

It is thus possible, starting with a value of B corresponding (say) to E, to cause B to follow the closed curve E F G K L E. This operation, in which the iron is finally brought back to its original magnetic condition, is called a cycle of magnetisation.

From Figs. 2 and 3, it is seen that a line parallel to the axis of B, drawn through any value of H, cuts the complete magnetisation curve in two points. Thus the value of B depends, not only on the value of H, but also on the magnetic conditions to which the iron has previously been subjected. This fact, first investigated by Professor Ewing, denotes that the magnetic properties of a substance are subject to *hysteresis*. Hysteresis is a general term which may be applied to any property of a substance when the value of this property depends, not only on the present treatment, but also on the past history of the substance.

The energy stored in unit volume of a magnetised substance has already been found* on the supposition that μ is a constant; since, however, μ is not constant for magnetic substances such as iron, steel, nickel, or cobalt, a further investigation is necessary in order to find the energy per unit volume of these substances. Let A B, C D (Fig. 4) represent the traces of two planes drawn perpendicular to the lines of force in a magnetised substance: the lines of force are represented by straight lines with arrow heads. Let the substance be magnetised by a field H equal to M N (Fig. 2), the value of B being equal to O M; and let us suppose that a very small increase in the value of H causes B to increase to O P. We may suppose this increase in B to be produced as follows: In the plane C D let there be a number of N magnetic poles, each of which is neutralised by an S pole with which it is associated; then if we remove a number of the N poles from C D and convey these to A B, leaving the S poles behind, we shall increase the number of lines of force passing from A B to C D, or, in other words, we shall increase B. Let the perpendicular distance between the planes

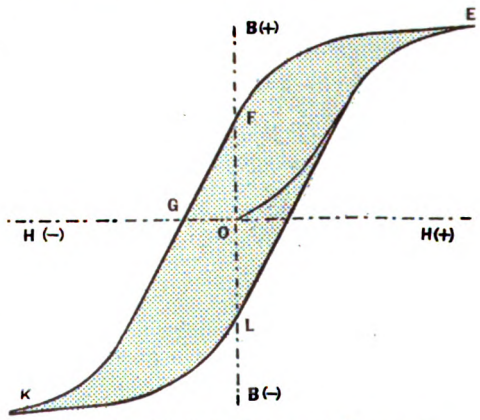

FIG. 3.—GENERAL FORM OF COMPLETE MAGNETISATION CURVE.

A B and C D be equal to d, and let the sum of the poles removed from unit area of C D and conveyed to unit area of A B be equal to m; then since H denotes the force acting on a unit pole at any point between the planes A B and C D, the work done in conveying the poles, of combined strength m, from C D to A B is equal to $H\,m \times d$. A unit pole gives rise to 4π lines of force, so that the poles of strength m give rise to $4\pi\,m$ lines of

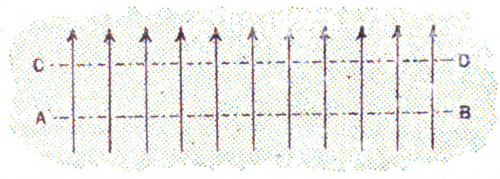

FIG. 4.—TO ILLUSTRATE METHOD OF CALCULATING THE ENERGY ABSORBED IN INCREASING THE MAGNETISATION OF IRON.

* TECHNICS, Vol. II., No. 12, December 1904, p. 579.

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force, which travel straight across from unit area of A B to unit area of C D; therefore $4\pi m$ will be equal to the increase in the lines of force per unit area passing from A B to C D, or to the increase in B: let this increase be denoted by b, which will be equal to M P, ig. 2. Then since $b = 4\pi m$, we have $m = (b/4\pi)$, and the work done in increasing B by the value b is equal to

$$Hm \times d = H\frac{bd}{4\pi}.$$

The work done is converted into potential energy stored in a space of unit area and thickness d; *i.e.*, in d cubic centimeters of the substance. Hence, the energy stored in unit volumes of the substance is equal to $(Hb/4\pi)$. But H is represented, in Fig. 2, by MN, and b by MP; therefore, Hb represents the area of the rectangle PN, and the energy stored per cubic centimeter of the substance due to increasing B from OM to OP is equal to the area PN divided by 4π.

We may divide the area ONERO (Fig. 2), into a number of elementary rectangles similar to PN; the area of each of these rectangles divided by 4π will represent the increase of energy per cubic centimeter due to a small increase of B, and consequently, if we start with the iron in an unmagnetised condition, and increase B from zero to OR, the energy stored per cubic centimeter of the iron will be equal to the area ONERO divided by 4π.

If we now gradually diminish H to zero, B will follow the curve EF, and the energy given up by the iron will be equal to the area REFR divided by 4π. Consequently, in increasing B from zero to OR, the work done by the electric current is equal to the area ONERO divided by 4π, and while B diminishes from OR to OF, due to the magnetising current falling to zero value, an amount of energy equal to the area REFR is returned to the electric circuit, with the result that an amount of energy equal to the shaded area ONEFO divided by 4π is lost to the electric circuit.

An extension of this reasoning shows that in performing the complete cycle EFGKLE (Fig. 3), the energy lost to the electric circuit is equal to the shaded area divided by 4π. If B and H are plotted on the scale of 1 c.g.s. line of force to a centimeter, the area of the cycle in square centimeters, divided by 4π, gives the energy, in ergs, lost to the electric circuit during a complete cycle.

On comparing the energy losses in different cycles, Mr. Charles Proteus Steinmetz has found that the energy lost per cycle is equal to $\eta B^{1.6}$, where B represents the maximum magnetic induction (OR, Fig. 2), and η is a coefficient which depends on the nature of the iron; thus for soft iron wire $\eta = 0.002$; for thin sheet-iron, $\eta = 0.003$; for thick sheet-iron, η varies from 0.0033 to to 0.0045; while for cast steel, $\eta = 0.008$. This result is of the greatest importance, as giving us a means of estimating the loss of energy due to hysteresis in the armature core of a dynamo, or the iron of a transformer.

We are indebted to Professor Ewing, not only for a very full investigation of the magnetic properties of iron and other magnetic substances, but also for a theory which explains the main characteristics of magnetisation. According to this theory, each molecule of a magnetisable substance is itself a magnet. A model of the molecular arrangement of such a substance can be made by supporting a large number of small magnets on needle points at equal distances from each other (Fig. 7). When these magnets are acted upon merely by their mutual attractions (*i.e.*, when no independent magnetic field acts upon them), they arrange themselves in groups such as are represented in Fig. 5. In this case the lines of force due to the magnets comprised in a group are almost solely confined to the space in the immediate neighbourhood of the group, and therefore, the whole combination of magnets

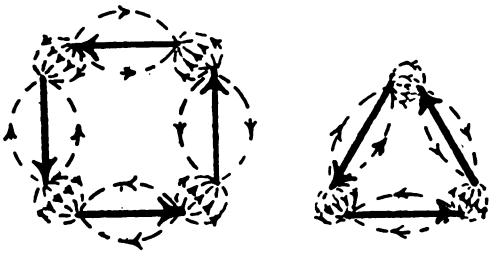

FIG. 5.—TO EXPLAIN MOLECULAR GROUPINGS IN UNMAGNETISED IRON.

produces no external field. This corresponds to iron, steel, nickel or cobalt in an unmagnetised condition.

If we now subject the combination of magnets to a gradually increasing magnetic field, the N pole of each magnet tends to follow the direction of the lines of force of this field, while each S pole tends to move in an opposite direction. Their original arrangement, however, was one of stable equilibrium; that is, a small displacement of any magnet called into play forces tending to bring the magnet back to its original position. As a consequence, when the independent magnetising field is small the magnets only turn

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through small angles; and if the field is removed, the magnets return to their original configuration. This corresponds to the initial part OC (Fig. 2) of the magnetisation curve; Lord Rayleigh has found that if unmagnetised iron is acted upon by a field less than 0·04 c.g.s. units, the magnetisation produced dis-

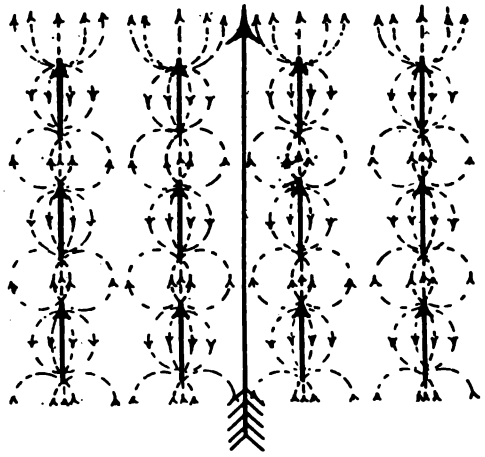


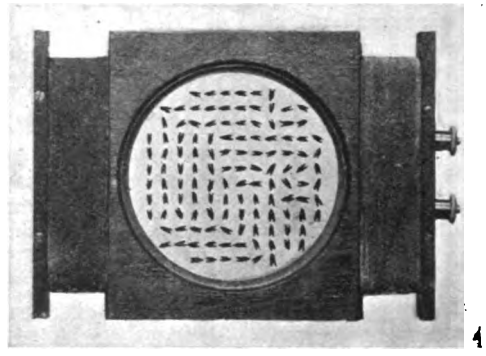
FIG. 6.—TO EXPLAIN THE MOLECULAR ARRANGEMENT OF MAGNETISED IRON.

appears at once on the magnetising force being removed.

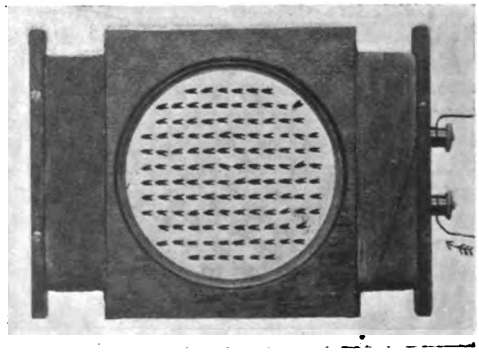
Although the configuration of the magnets is stable with regard to small displacements, nstability sets in when the displacements become large, and the magnets suddenly swing round so that their N poles all point in the direction of the magnetising field. This kind of limited stability is very common; it is exhibited, for example, by an ordinary chair which, on being tilted through a small angle, falls back to its original position when free to do so; if tilted through more than a certain angle, it suddenly falls over on its side. Hence, when the magnetising force acting on the molecules of soft iron exceeds 0·04 c.g.s. units, the molecules commence to turn in groups, with the result that the value of B increases much more rapidly than H. This condition corresponds to the part CD of the magnetisation curve; at D all the molecules have swung round so that their N poles point in the direction of H, and a further increase in H can cause them to turn no farther.

When the magnetising force H is diminished to zero, the molecular magnets do not swing back to their original positions. They only turn through small angles and acquire a new state of equilibrium, which is not, however, so stable as the state in which they were originally arranged. Consequently B has a fairly large value when H is diminished to zero (Figs. 2 and 3), and a reverse magnetising force is necessary to reduce the magnets to the positions indicated in Fig. 5. In the case of soft iron, mechanical vibration is generally sufficient to cause the molecules to swing round to their neutral position.

We can now understand the physical foundation for the principles previously deduced. On referring to Fig. 6, it will be noticed that five lines of force pass directly from the N pole of an elementary magnet to the S pole of the magnet in front of it; if we confine our attention to the layer of magnetic molecules lying side by side in one square centimeter cross-sectional area, then the lines of force proceeding directly from the N poles of these to the S poles of the molecules lying in front of them will constitute the part of B due to the magnetised iron; *i.e.*, these



Arrangement of magnets in absence of magnetising field.



Arrangement of magnets under influence of magnetising field.

FIG. 7.
APPARATUS TO EXPLAIN THE MAGNETISATION OF IRON ACCORDING TO EWING'S THEORY.

(This model is made by the West London Scientific Apparatus Co., Deodar Road, Putney.)

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lines of force are equal in number to $4\pi I$. Let us call these the *direct* lines due to the molecules. At the end of the magnet (say the top of Fig. 5) lines of force will proceed from each N pole at the bounding surface, and proceed through the air.

If a unit N pole is carried one centimeter through the magnetised substance in the direction of magnetisation, then the work done is, by definition, equal to $H \times 1$, and therefore H denotes the *average* force acting on a unit N pole while it is carried through a centimeter distance in the direction of magnetisation. On referring to Fig. 5, it will be seen that some lines of force proceed from the N to the S pole of the same magnet, and these, which we may call the *reverse* lines, run in a direction opposite to the direct lines defined above. In carrying a unit N pole through one centimeter in the direction of magnetisation, it will in parts of its path be acted upon by the direct lines, and in other parts by the reverse lines. We have already found that, in the interior of a very long and narrow iron rod placed within a magnetising solenoid, the force per unit pole is the same as if the iron were absent. This means that, so far as concerns the lines of force due to the magnetic molecules, no work is done in carrying a unit N pole through a distance of one centimeter in the direction of magnetisation, the action of the direct lines in some parts of the path being just neutralised by that of the reverse lines in other parts of the path; thus the only work done is that due to the magnetising field produced by the current in the solenoid windings.

In the case of a short permanent magnet acted upon by no independent field, no resultant work is done in carrying a unit pole from the S to the N pole through the interior of the magnet and then back again to the S pole along any path outside the magnet. This follows as a consequence of the fact that the path chosen does not embrace any current, and the work done in carrying a unit pole round a closed path is equal to 4π times the current embraced. Now we know that in proceeding from the N to the S pole outside the magnet we are following the course of the lines of force in air; and since the magnet is supposed to be short, there will be an appreciable field at each point of the path chosen, so that on the whole the unit N pole gains energy in this part of its path. Hence it follows that in the part of the path within the interior of the magnet, from the S to the N pole of the latter, the unit N pole must lose energy, or its motion must, on an average, be opposed; this is due to the fact that the N pole of the magnet sends some lines of force back *through the magnet* to the S pole, thus increasing the number of the reverse lines, and diminishing the number of the direct lines. This tends to render the magnetisation of the magnet somewhat unstable; it is well known that a short magnet tends to demagnetise itself, and therefore where an electro-magnet is required to lose its magnetism as quickly as possible after the cessation of the magnetising current, a short, thick cylinder of soft iron is used as the core of the magnet. On the other hand, the poles of a long, thin magnet produce little reversing effect, since they are, on an average, at a considerable distance from points within the magnet; this is one of the reasons for using a long rod in determining the permeability of iron. When iron is formed into a closed ring there are no poles, and therefore there is no reversing action.

ERRATA.

(TECHNICS, No. 13, Vol. II., January, 1904.) In Part IV. of "The Electro-Magnetic Theory" on page 42, first column, 9th line from bottom, for "the practical unit of power" *read* "the practical unit of potential difference."

Page 45, first column, 13th line from top, for "$(B \cos l\,C)v$" *read* "$(B \cos \theta.\, l\,C)v$."

Page 45, second column, for "$2r$ F" *read* "$2\pi r$ F."

(To be continued.)

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SPECIAL DEVICES USED IN WEAVING.

Part V.—Warp Pirn Winding Machine.

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By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

IN a former article it was observed that weft yarn is sometimes dyed and bleached when in the form of mule cops, but more frequently in the form of hanks which are subsequently re-wound on to pirn bobbins or paper tubes by one of the numerous systems of pirn winding, several of which have been previously described in this series of articles. Cop-dyed yarn, however, is not generally so evenly dyed as hank-dyed yarn, in consequence of the compactness of yarn preventing the free access of dye to the innermost and, therefore, obscured part of a cop, whether the process of dyeing is conducted on the vacuum or on the pressure principle: hence cop-dyeing sometimes produces what is termed "shaded" yarn—*i.e.*, yarn of an irregular colour value.

Yarn is in the best possible condition for dyeing or bleaching when in a perfectly open and free state, as hanks or warp-chains. In either of these forms every portion of yarn is more completely and equally exposed to the dye liquor than when in a compact state, as in cops, on spools, or warp-beams. It is also generally admitted that warp- or chain-dyeing yields a more uniform tone of colour than is obtained by hank-dyeing. This belief has induced some manufacturers to adopt the novel expedient of preparing weft yarn as a ball or chain warp, to be dyed (and sized if required), after which the respective threads are simultaneously delivered to, and wound at a uniform velocity upon, a corresponding number of pirn bobbins or paper tubes, by means of what is known as a "Warp Pirning" machine, illustrated in Fig. 26.* The essential parts of this machine are represented in detail in Figs. 27, 28, and 29, which show a sec-

* For permission to use this illustration the writer here expresses his obligation to Messrs. Thomas Holt, Ltd., Rochdale, who make the machine, and who introduced it into England, from America, in the year 1896.

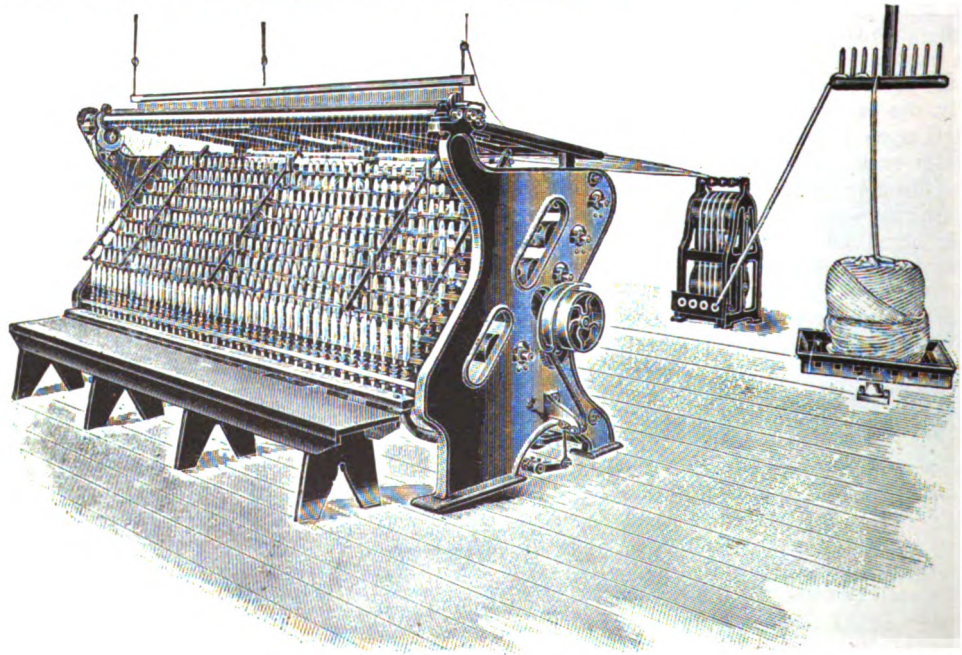

Fig. 26.—Warp Pirning Machine.

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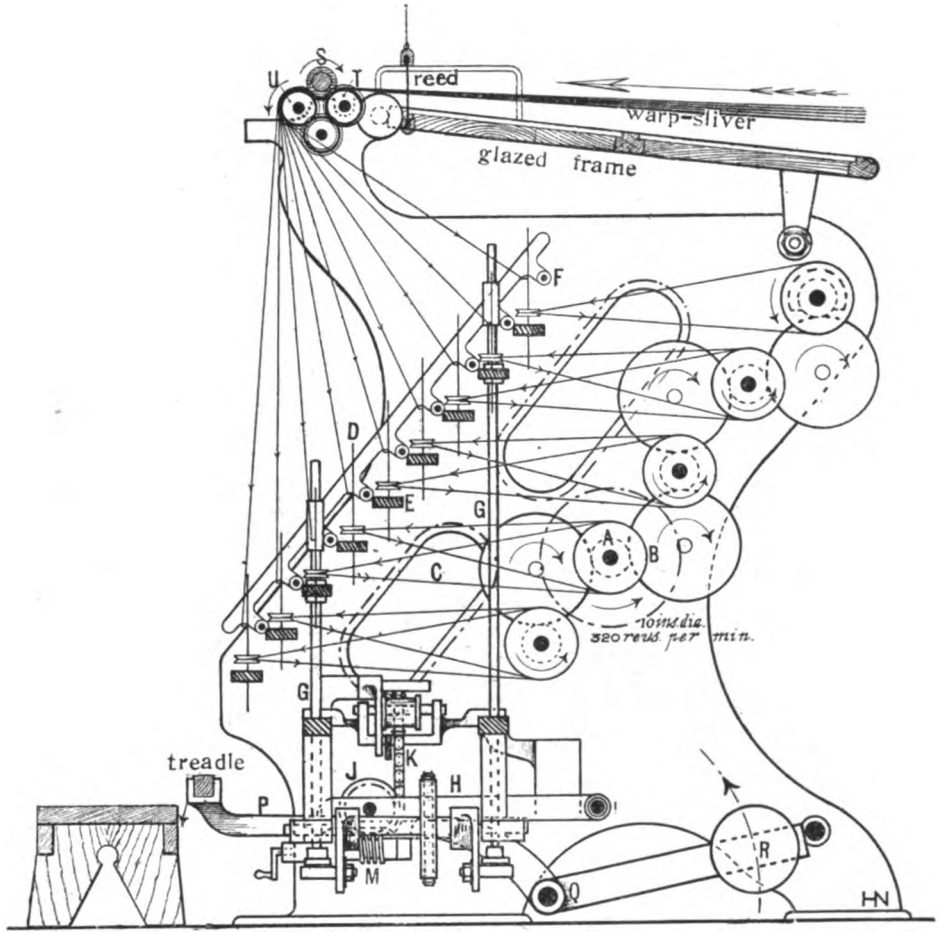

FIG. 27.—SECTIONAL ELEVATION OF WARP PIRNING MACHINE.

tional elevation, a part front elevation, and a part plan of the machine respectively.

The machine contains 378 spindles, arranged vertically in nine horizontal rows, with 42 spindles in each row, and supported by nine cross rails E, fixed in different planes both vertically and horizontally. Each successive rail from the bottom one is placed $3\frac{1}{8}$ inches higher than its predecessor, and $2\frac{1}{2}$ inches to the rear of it when viewed from the front of the machine. Thus, when viewed endwise, spindle rails are situated four inches apart, diagonally, so that the nine rows of spindles form a steep bank inclined at an angle of 40 degrees to a vertical plane. This arrangement of spindles not only economises floor-space, but it affords easier access to all the bobbins for the purpose of piecing broken threads, of removing full bobbins, and replacing them with empty ones, than would be afforded by placing all spindles in the same horizontal plane.

Spindles D (but not bobbins) are driven at a uniform velocity by means of cotton bands C, from five tin drums B, extending from end to end, and situated at the rear of the machine, with their axes placed eight inches apart in a diagonal plane that is parallel to the bank of spindles. The drum shaft, A, second from the bottom, carries a fast or driving pulley fixed at one end, and thus becomes the prime motor of the machine. Next to the fast pulley is a narrow slow-motion pulley to operate slow-motion gearing, and this is followed by a loose pulley on the inside. The remaining four tin drums are driven positively, by means of toothed wheel gearing, as shown; and each drum, excepting the top one, drives two rows of spindles. The slow-motion gearing is identical in principle with that of most modern slasher sizing machines, and is applied with the same object, namely, of starting a machine at a slow speed, to be followed by the full speed, thereby

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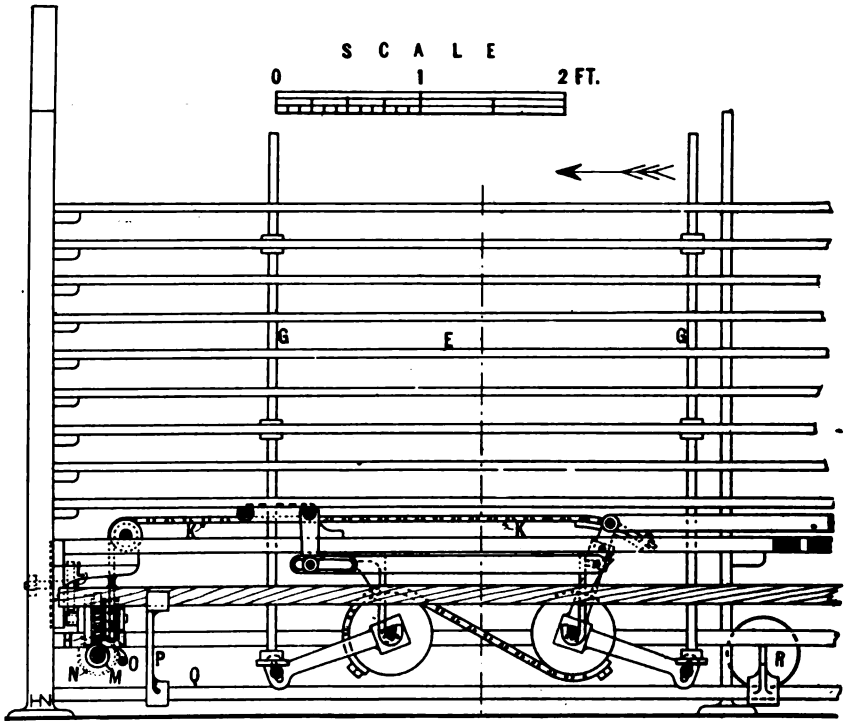

FIG. 28.—PART FRONT ELEVATION OF WARP PIRNING MACHINE.

preventing a sudden strain upon yarn such as would occur if a machine were started at full speed. By depressing a treadle, which extends right across in front of the machine about ten inches above the floor, a strap-fork passes the driving strap from the loose pulley, first on to the intermediate narrow pulley (which sets the slow-motion gearing in operation), and then on to the fast or full-speed driving pulley. When the driving shaft attains a velocity in excess of that developed by the slow-motion gearing, the latter automatically becomes inoperative.

In its passage from a ball-warp to the pirn bobbins, yarn is subjected to the requisite degree of tension by passing several times around two tension drums, to facilitate the separation of threads only between them and the drawing and delivery rollers S, T and U. On leaving the tension drums the threads diverge from their condensed or sliver form, and expand into a broad sheet as wide as a long row of spindles. Their separation is assisted by means of a reed, situated immediately behind the drawing and delivery rollers, between which they pass. The upper roller S. which is of great weight, and covered with rubber to better grip yarn and prevent injury to it, rests freely upon and between the two lower rollers T and U, which are driven positively in the same direction, by means of a linked chain and toothed wheels. Thus, by revolving against both rollers T and U, roller S serves to withdraw yarn from its source, and deliver it to the pirn bobbins or paper tubes at a uniform velocity.

From the delivery rollers threads pass through guide-wires on to their respective bobbins placed head downward upon spindles; on these bobbins the threads are built up in a succession of ascending conical layers until they are filled. Guide-wires are carried by nine guide-rails F, situated one immediately behind each row of spindles, and supported by means of vertical poker rods G, to which is imparted a reciprocal vertical motion, so as to guide threads between the bases and apexes of bobbins. Guide-rails are actuated by means of a building motion controlled by a cam L, in such a manner that they ascend quickly and descend slowly, thereby causing threads to be placed in alternate layers of coarsely-pitched and finely-pitched coils respectively, on the same principle as that on which mule cops are built up, although these are formed with a quick downward and slow upward traverse. This principle of winding causes a thread to frequently cross and re-cross upon itself, and thereby bind itself together with greater firm-

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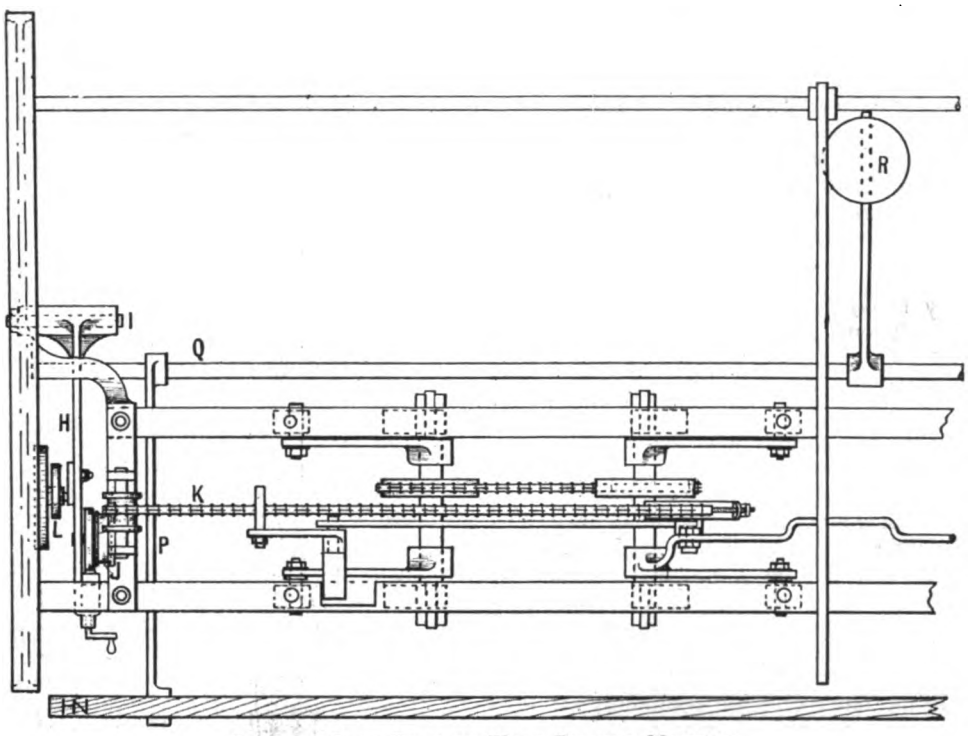

FIG. 29.—PART PLAN OF WARP PIRNING MACHINE.

ness and compactness than is possible with a slow uniform traverse in both directions. As cam L revolves it acts upon a bowl or runner, carried by a treadle lever H, fulcrumed at I, which also carries a chain pulley J, to which one end of a chain K is fastened. Thus, as the treadle lever is depressed, the chain pulley (which is prevented from revolving) descends with its chain, and by a suitable combination of chains, chain pulleys, connecting rods, and levers, the pokers supporting guide-rails are raised positively; but their descent is accomplished by gravitation, or negatively.

In addition to their reciprocal vertical movement to guide yarn between the bases and apexes of bobbin cones, the building motion also gradually and intermittently raises guide-rails bodily, on the completion of each upward movement by them, thereby causing yarn to be placed in successive ascending layers along a bobbin or paper tube until it is completed. This is effected by causing the teeth of a ratchet wheel N, carried on the forward end of a shaft attached to treadle lever H, to become engaged with a pawl or catch O, which imparts a slight turning movement to the shaft on the completion of each downward stroke of the treadle lever. On the ratchet wheel shaft is a worm M, whose thread engages with a worm wheel that is compounded with the chain pulley J. Thus, as the ratchet wheel turns, it causes a short length of chain to be wound on to the chain pulley, thereby raising the guide-rails as described.

With such a building motion it will be evident that all bobbins in the machine must build up from their initial to their final stage simultaneously, and not independently, as in other pirn-winding machines. This circumstance necessitates the removal or "doffing" of all bobbins at the same time. Previous to doffing, however, guide-rails are lowered so as to convey all threads below their respective bobbins, for the purpose of winding a little yarn on to the friction collars on the spindles, and thereby save the time and trouble of re-attaching threads separately to a new set of bobbins. Also, in order to start up a new warp in the machine, its threads are separately twisted to those forming the remnant of the finished warp, in a manner similar to that by which a new warp is twisted to an exhausted one in a loom.

The particular form of winding spindles employed in this machine constitutes one of the most important features worthy of special attention, as upon these its efficiency largely depends. They are a modification of the

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well-known Rabbeth or self-contained type of spindle, constructed on what is variously termed the "top," "elastic," "self-balancing," "flexible," and "gravity" principle (which terms will be presently explained), and are expressly designed to meet the special requirements of this machine. Thus, although spindles revolve with a uniform velocity, bobbins or tubes are so mounted upon them that the bobbins are driven frictionally, so that they may slip upon their spindles, and thereby automatically retard or accelerate their velocity as yarn is guided towards the bases or apexes of bobbin cones respectively, thereby ensuring a uniform rate of winding that always coincides with the rate of delivery. Such provision, as stated on a previous occasion, is necessary in any machine in which a number of threads are simultaneously and continuously delivered from a common source (as a ball-warp), and not from independent sources (as cops, bobbins, and hanks), to be wound on to separate bobbins, tubes, or spindles. In the former case the rate of supply of yarn determines the rate of winding; but in the latter case the conditions are reversed, and the rate of winding determines the rate of supply. For example, if threads were delivered from a ball-warp, to be wound upon pirn bobbins revolving with a *uniform* velocity, it would be necessary to deliver yarn at a variable velocity, to counterbalance the varying diameter of the bobbin cones.

The construction of a winding spindle is illustrated in part section in Fig. 30. A spindle shank A is furnished with a tightly-fitting wharve B, fixed about 2¼ inches from the spindle foot. The upper portion of a spindle shank is furnished with a heavy flanged collar or friction disc C, surmounted and gripped by a barrel or balloon spring D, on which a bobbin or paper tube is fixed head downward, and firmly gripped internally by the spring. The friction disc, spring, and bobbin are all free upon the spindle, and supported by the wharve, which is separated from the collar flange by a flannel washer, to reduce frictional resistance between them. This constitutes the frictional driving principle of the spindle, which enables the friction disc and its bobbin to slip on the spindle, and thereby automatically regulate its velocity as required by the varying diameter of a bobbin cone, and also to neutralise any irregularity of tension of its particular thread. Thus, the velocity of a bobbin will gradually diminish as its thread is guided towards the base, and gradually increase as the thread approaches the apex of its cone. The lower

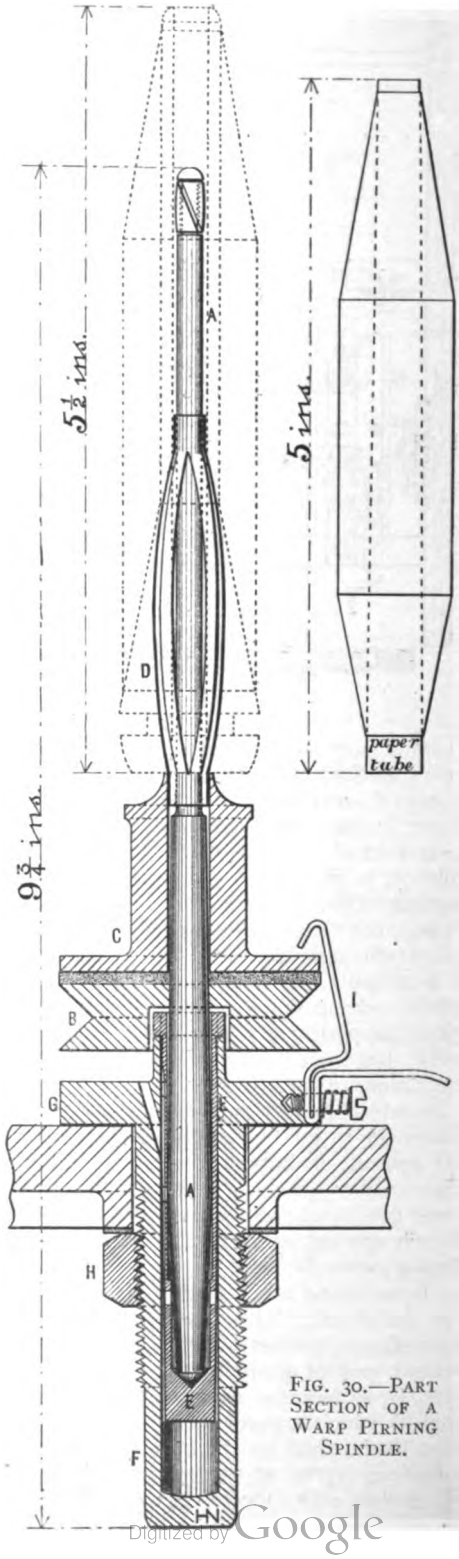

FIG. 30.—PART SECTION OF A WARP PIRNING SPINDLE.

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portion of a spindle shank revolves in a long sleeve bearing or cup E, retained within a hollow bolster F, which supports the entire spindle and enables it to be securely fixed, with only one setting, in a spindle rail: hence the self-contained principle. For the purpose of fixing a spindle to a rail, the bolster is formed with a large flange G near the top, whilst its body is partially threaded and furnished with a nut H. The bolster also provides an oil chamber, to contain a supply of oil for the self-lubrication of a spindle. This is effected by drilling several small holes in the spindle bearing E, and connecting them by a narrow groove or channel formed down one side, to permit of oil rising to the spindle. The sleeve E is formed with a rim at the top, which rests upon the ridge of the bolster. The rim is formed with two projecting pieces that fit into small grooves at opposite sides of the bolster ridge, to prevent the footstep revolving with the spindle. A flexible hook I, loosely attached to the bolster flange by means of a small screw, is held by a spiral spring over the friction disc C, to prevent accidental withdrawal of the latter on removing a bobbin from a spindle.

The elastic or self-balancing principle is obtained by slightly tapering the outer surface of the spindle bearing E, in both an upward and a downward direction, with three-quarters of an inch nearer the top left parallel. The object of this is to provide a bearing that will permit of a limited amount of flexibility of movement by a spindle. Such provision enables a rapidly revolving spindle, that is not in perfect balance, to automatically change the position of its normal axis until it discovers its true axis of gravity, when it will become perfectly balanced or counterpoised, and will continue to revolve with perfect steadiness around that centre of gravity.

A warp-pirning machine constitutes a distinct type unlike any previous winding machine; and whatever may be its true commercial value as an integral part of a whole system, it is one which, as an abstract unit, possesses many excellent features. As there is an entire absence of frictional contact and compression of yarn against any surface during winding, two of the worst evils usually associated with ordinary pirn winding (*i.e.*, flattened and glazed or burnished yarn) are avoided, and yarn retains its strength, roundness, and normal tone of colour. Also, the building up of yarn upon a bobbin or paper tube, with a slow downward and quick upward traverse, produces a firm and compact bobbin containing a greater length of yarn,

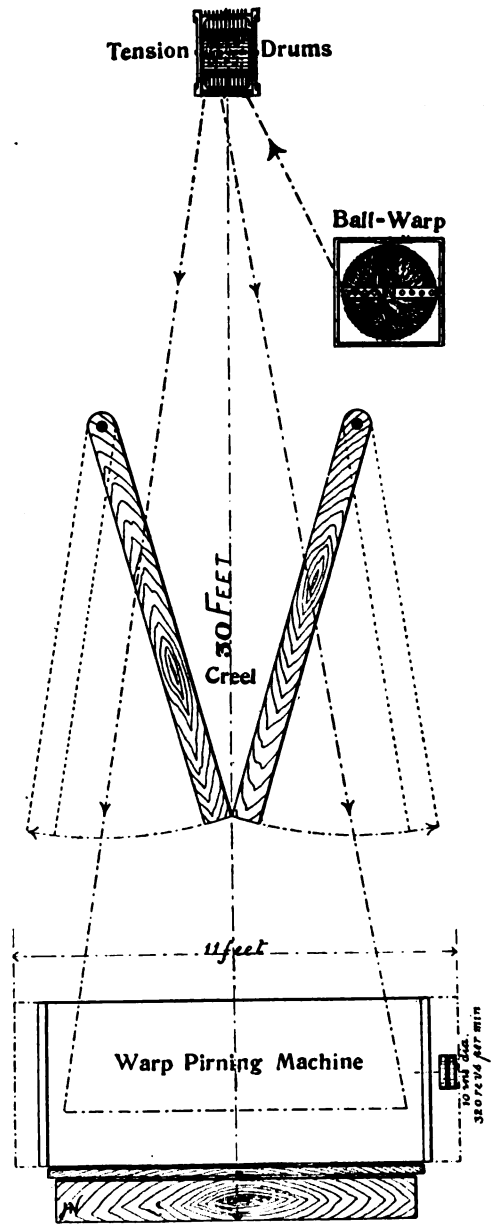

FIG. 31.—BLOCK PLAN, SHOWING HOW A WARP PIRNING MACHINE MAY BE EMPLOYED TO WIND YARN EITHER FROM A BALL-WARP, OR FROM SPOOLS CONTAINED IN A V-CREEL.

and one that is free from "lapped ends." This term describes an evil that sometimes exists in pirn bobbins in which the portion of a thread that should form the outer layer cuts into previous layers of yarn, and becomes buried below the surface, thereby causing breakages of weft during weaving. Other

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advantages claimed for this machine by the makers are summarised as follows, namely: That greater economy is effected, and a superior quality of yarn produced, by dyeing yarn when in the form of a condensed and continuous sliver, and afterwards re-winding it on to pirn bobbins, than would accrue by hank dyeing. A brighter and better quality of goods, because of the absence of "shaded" yarn. Greater freedom from knots in yarn, and less waste. An increased production per loom, resulting from the better quality of weft and absence of "lapped ends" on bobbins. The utilisation of soft, tender, insufficiently-sized, or otherwise imperfect yarn of warps, which may be transferred on to pirn bobbins and used as weft. And greater production of weft at less cost in wages, as the machine may be attended to by a young employé, who stands on a long form extending in front of the machine, and controls the driving strap by means of a treadle, which is carried by arms secured to shaft Q, and is just more than balanced by a balance weight R, carried by a lever, also fastened to shaft Q. The treadle is depressed by the feet of the operative to set the machine in operation; and, on releasing the treadle, the weight R falls by gravitation, thereby causing the driving strap to pass from the fast to the loose pulley, when the machine stops. The machine may also be employed to wind yarn from warpers' spools, cheeses, or bobbins, held in a V-creel, as shown in the block plan, Fig. 31. The creel is specially constructed so that the two halves may be swivelled outward from the centre (as indicated by dotted lines), to give a clear passage for yarn when it is required to wind from ball-warps.

As regards the claim that warp dyeing yields superior results to hank dyeing, in respect of uniformity of tone of colour, a little reflection will show that, although that is true in respect of warps, it is not so true if warp-dyed yarn is used as weft, whereby those results become nullified, as will be seen presently. This may, at first, appear paradoxical, until the two systems of dyeing are compared. In hank dyeing, hanks are immersed in the dye vats in batches: hence (unless a perfectly soluble dye is used) the dye becomes weaker, by absorption, as each subsequent batch of hanks are dyed, thereby producing hanks of irregular colour value. In warp-dyeing, however, the yarn passes through the dye as a continuous sliver; and, although all the threads in the warp will be dyed alike, the colour-value will gradually become less as the dye is absorbed, so that the tone of colour will be darker at the initial than at the final extremity of the warp. Therefore, assuming each thread to be entirely contained on a pirn bobbin, and used as weft, the darker tone of weft from one bobbin will be juxtaposed with the lighter tone of weft from another bobbin, and thereby produce a shaded effect in cloth.

The warp-pirning machine herein described formed the prototype of another machine made by the same makers, and patented by them in September, 1899, for the purpose of winding yarn from ball warps on to warpers' bobbins. The modification chiefly consists of a different form of both winding spindle and traverse motion suited to warpers' bobbins, which latter are frictionally driven, whereby they may slip upon their spindles, and so automatically retard their velocity to compensate for their increasing diameter, and thereby maintain a uniform rate of winding.

METALLIC CALCIUM.

THE commercial preparation of an alloy of calcium and aluminium has recently been accomplished by the firm of Poulenc Frères, of Paris. More recently Dr. Rathenau, of Berlin, has been able to prepare the pure metal in considerable quantities by the electrolysis of melted fluorspar. The applicability of the metal to commercial uses has not yet been demonstrated, but it is suggested that the aluminium calcium alloy might be used for eliminating the blow-holes of cast steel. The gases contained in these hollows consist of carbon monoxide and air. It is suggested that whilst the aluminium reduces the monoxide the calcium would absorb both the oxygen and nitrogen, and that an aluminium-calcium steel would be entirely free from blow-holes.

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SOME DEFECTS FOUND IN TIMBER, AND THEIR CAUSES.

By HAROLD BUSBRIDGE, A.R.C.Sc., A.R.I.B.A.

THE defects which remain for consideration are those which are seldom or never found in growing trees, but which develop after felling.

Without doubt the most common defect of this kind is the side-shake, also sometimes called wind-shake, weather-shake, or drying-shake. It consists of splits running from the circumference towards the centre of the log, and it may at once be distinguished from heart-shake and star-shake by the fact that the clefts are always widest at the circumference, diminishing in width towards the centre. Figs. 1, 2, 6 and 10 of the article on "The Shrinkage of Timber," published in No. 7 of TECHNICS, afford numerous examples of "side-shake." It is generally caused by allowing timber to season in the log or in baulk, when the exterior dries more rapidly than the interior, and shrinks with the result that the wood "opens." The same causes which operate in warping, as already described in the article referred to, also tend to produce side-shake, and the defect is aggravated when drying is hastened by exposure to sun or wind.

Most timbers decay more or less rapidly when exposed even to a dry atmosphere, but the process is immensely hastened when the timber remains in a damp condition, or when the air is heavily charged with moisture. The process, in most woods, is then more rapid than when kept completely immersed, owing to the oxidation of the wood substance which takes place. Decay is probably also accelerated by the destructive action of microbes.

It is well known that unseasoned timber decays far more rapidly than that which has been properly seasoned. This is partly accounted for by the fact that unseasoned timber contains a great deal of liquid sap which, under favourable conditions, is very liable to ferment, and thus decay is set up in the wood substance. In properly seasoned timber the liquid has been either washed out by a stream of water, or has been evaporated to dryness in the pores of the wood, so that fermentation cannot begin in the latter case until a sufficient amount of water has been reabsorbed. When decay has once begun, it rapidly develops and spreads, until the whole piece has been destroyed. Fig. 1 represents pieces of willow in various stages of decay. These specimens were all cut from different parts of the same log, which had been lying neglected in a damp place. The first brown

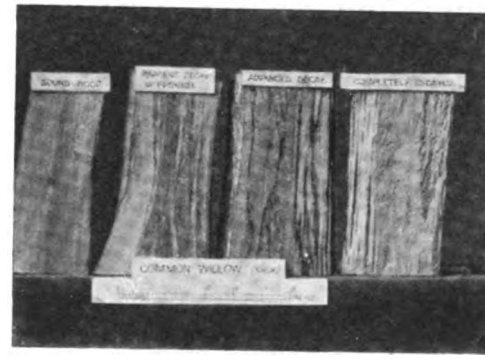

FIG. 1.—"FOXINESS" IN TIMBER: WILLOW (*Salix*).

The samples from left to right represent: (1) *sound wood;* (2) *incipient "foxiness";* (3) *advanced "foxiness";* (4) *complete decay.*

or reddish streaks which appear in affected timber are known as "foxiness," and such timber is said to be "foxey." The wood has lost a great deal of its strength and works "dead" and short under the tool. When decay has proceeded further, the discoloration is often more marked, and the wood becomes quite soft and brittle.

The last stage of decay is reached when the timber has lost a great deal of its substance, and what remains is little better than a mass of soft pulp. It has little or no coherence, and is quite useless, even for firewood.

The majority of timbers decay most rapidly when they are exposed alternately to wet and dry conditions; as, for example, fence posts just above the point where they enter the ground. The chemical or bacterial destruction is often hastened and assisted by the attacks of various kinds of fungi and by insects. Fig. 2 shows a piece of fir timber partially destroyed in this manner, and from the fact that this kind of decay generally sets in only where there is an excess of moisture, it is termed, by practical men, "wet rot."

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FIG. 2.—DECAYED FIR TIMBER.
Decay due to contact with damp earth and lime mortar.

"Dry rot" is so called because it is often seen under apparently dry conditions, although investigation has proved that a small amount of moisture is always necessary before wood can be attacked by it. It is really a disease to which soft woods are especially liable, caused by a species of fungus technically known as *Merulius lacrymans*.

The spores of this plant are quite microscopic, so as to be easily blown about by the wind, and there is no doubt that they adhere to the sides of rough timber, to workmen's clothes and tools, and even to the coats of animals. In this way they are carried in all directions, and perfectly sound timber is always liable to their attacks, provided only that conditions are favourable to their germination and growth. The conditions necessary to the life of this parasitic fungus appear to be: (1) The presence of an alkali, such as ammonia; (2) a warm, stagnant atmosphere; (3) a certain amount of moisture, as, for instance, in a damp atmosphere. It follows that, wherever the conditions are favourable, any spores which may have already attached themselves to timber will germinate, and cause an outbreak of "dry rot." The spores germinate on the surface of damp timber, sending their germinal filaments into the tracheides, boring through the cell walls, and extending rapidly in all directions. The fungus mycelium, as it gains in strength by feeding upon the wood substance, completely destroys the timber.

Timber, when badly attacked by "dry rot," contracts excessively in all directions, and transverse cracks appear, like those seen in charred wood (see Fig. 3). Very often the outer surfaces of boards become convex, and when touched they yield to pressure, being so weak as to be easily broken by the fingers. The wood turns brown, loses much of its weight, and all its strength.

Dry rot often breaks out in ill-ventilated ground floors of houses, and in wood fixed against damp walls. When removed, the inner surfaces of the boards are found to be

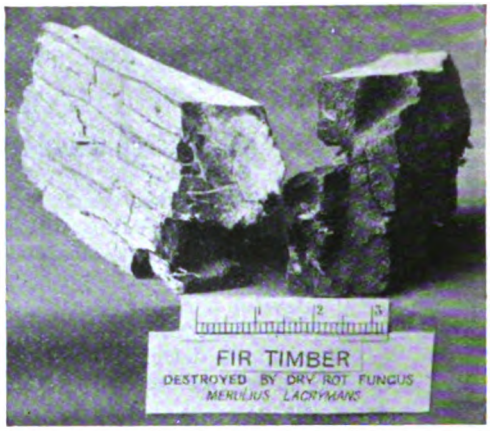

FIG. 3. FIR TIMBER DESTROYED BY DRY ROT FUNGUS (*Merulius lacrymans*).

covered, as in Fig. 4, with a mat-like growth of mycelium, having a silky lustre, and in colour varying from greyish-white to rich orange yellow, being sometimes even of a violet hue.

In places the vegetable growth thickens out into a flat cake-like mass, upon which tear-like drops of water may be seen; from this the fungus takes its name—*Merulius lacrymans*.

FIG. 4.—FIR TIMBER DESTROYED BY DRY ROT FUNGUS.

Fig. 3 shows the appearance of wood which has been destroyed by this fungus, after the mycelium has been removed.

In order to prevent dry rot, the most reasonable method is to avoid or prevent the conditions already referred to as necessary for the growth of the fungus. Thus, none but thoroughly dry timber should be employed. Spaces under floors and behind

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woodwork should be thoroughly ventilated; wood should never be placed in contact with damp brickwork or masonry, and ammoniacal fumes from decomposing animal matter should be carefully avoided. It should also be remembered that an outbreak can never occur without the previous presence of spores of the specific plant concerned. It is not so easy to check the ravages of "dry rot" when once it has taken hold of a building. The rootlets (*hyphae*) and felt-like surface-growths spread with amazing rapidity, covering brick and stone work, and even earth, in their attempts to reach sound wood; besides, millions of spores are disseminated in all directions, and these germinate upon other timbers. The only safe course is to take out every particle of affected wood from the building, and to immediately burn it. Any remaining timber should be treated either with hot coal tar or oil of creosote, if out of sight; or with a solution of some other powerful antiseptic, such as corrosive sublimate, if exposed to view. It should, however, be remembered that these applications destroy the fungus only where they come into contact with it, and that the centre of a beam treated with them may be full of living fungus, which, under favourable conditions, may spread to new wood.

Other forms of fungus are known which attack timber, one of these being *Polyporus vaporarius*, which attacks timber in a very similar manner to *Merulius lacrymans;* its effects are manifested by the brown and red streaks sometimes seen in freshly sawn timber. In bad cases the wood even becomes rotten and powdery. The mycelium of this fungus is perfectly white, and not grey like that of merulius; and whereas the former is not uncommonly found in the forest, the latter is exclusively a domestic disease.

Another disease of pine wood, due to the fungus *Polyporus mollis*, is also known, and its effects are similar to those last described.

When cut into planks or scantlings, timber is sometimes found to be mottled or spotted, instead of having the even colour indicative of sound wood.

The spots are generally from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in. in diameter, are of lighter colour than the surrounding wood, and wanting in lustre. At these points the wood is soft, deficient in strength, and is ultimately reduced to powder. Such timber is said to be "doaty." "Doatiness" is seen most frequently in beech, hornbeam, plane tree, pear tree, and apple; and

FIG. 5.—TO ILLUSTRATE "DOATINESS" AND "DRUXY KNOT."

timber affected with it is almost worthless. Fig. 5 shows a piece of doaty beech containing a druxy knot.

We now have to consider the ravages made in timber by various insects. Fortunately, in England the damage from this source is not very extensive, although sometimes beech, oak, and other woods are found to be seriously "worm-eaten," as in Fig. 6 The chief offenders are the larvæ of various insects, which perforate the wood in all directions, their borings being commonly termed "worm-holes." Among the insects known to bore into wood are the larvæ or maggots of the wood leopard (*Zeuzera æsculi*), saw-fly or giant wood wasp (*Sirex gigas*), steel-blue wood wasp (*Sirex juvencus*), goat moth (*Cossus ligniperda*), giant ichneumon (*Urocerus gigas*), and *Dorcus parallelopipedus*.

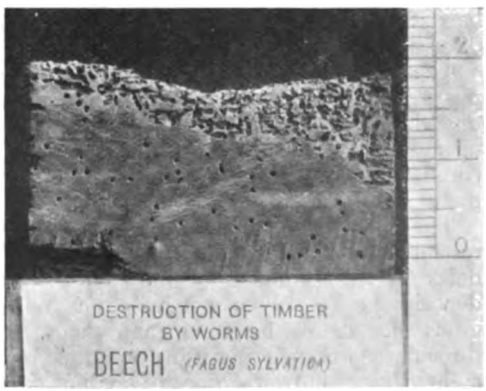

FIG. 6.—BEECH DESTROYED BY WORMS.

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The wood wasps (*Siricidæ*) deposit their eggs during the summer in the bark of trees or in posts, by means of a pair of saw-like instruments attached to the abdomen of the female. The maggots which hatch from these eggs tunnel right into the wood, remaining there during the winter. When the perfect insects are ready to emerge, they eat their way out of the tree, leaving behind them the holes visible in Fig. 7, which shows pieces of pine timber perforated by *Sirex juvencus*.

Fig. 8 shows a piece of ash perforated by larvæ of *Dorcus parallelopipedus*.

The larvæ of the goat moth burrow into the wood of various trees, such as apple and pear, and form large tunnels in the heartwood, where they feed for nearly three years, although sometimes they leave the trees for a time. When mature, they turn to large

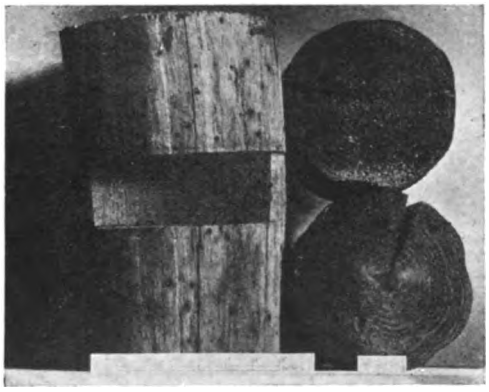

FIG. 7.—PINE TIMBER PERFORATED BY *Sirex juvencus*.

brown pupæ near the entrance to their borings. Their ravages cause the tree to decay and become generally weakened, and thus easily blown down. Their presence can be detected by the exit holes, and by the diseased patches they form.

The best way to destroy these larvæ is to place pieces of stick cyanide of potassium in the entrances of the tunnels, closing them up afterwards with clay. Cart grease and paraffin may be smeared over the trunks of the trees in June, to prevent egg-laying.

The giant ichneumon has an ovipositor resembling a gimlet, which it uses to bore holes in living timber for the purpose of depositing eggs. When hatched, the young grubs immediately begin to gnaw their way through the wood, boring it in every direction, and making burrows of considerable size. The wood preferred is generally fir and pine, which is sometimes completely riddled by them.

In tropical countries great havoc is often wrought by white ants (*Termites*), which always live in vast colonies. They are miners, and under no conditions do they permit any sign of their ravages to appear upon the surface. Their mouths are furnished with jaws which move transversely, and nothing, unless cased in metal, can resist their attacks. They have been known to destroy the whole woodwork of a house in a single season.

Always working in darkness, they will often eat through the floor and remove the whole

FIG. 8.—ASH TIMBER PERFORATED BY LARVÆ OF *Dorcus parallelopipedus*.

interior of table and chair legs, leaving a shell no thicker than paper.

The first intimation of the damage done is when the article crumbles to dust on a weight being placed upon it; a staircase has been known to fall to pieces as soon as a foot was placed thereon.

Fig. 9 represents a piece of wood destroyed by white ants in eighteen months; the damage represented in Fig. 10 was done in forty-eight hours only.

According to Mr. Britton, the following Colonial woods are said to resist the attacks of white ants: *America*, butternut, pitch-pine (partially); *Australia*, jarrah, Huon pine; *British Guiana*, greenheart; *Ceylon*, ebony,

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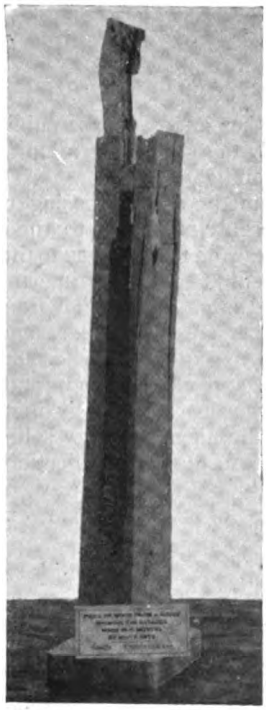

FIG. 9.—PIECE OF WOOD FROM A HOUSE, SHOWING THE RAVAGES WORKED BY WHITE ANTS DURING EIGHTEEN MONTHS.

ironwood; *India*, cedar, sandal, teak; *West Indies*, bullet-wood, lignum vitae, quassia-wood. In many of these cases, however, the wood is attacked as soon as its characteristic odour has passed off.

One other pest may be alluded to, *viz.*, the *Teredo navalis*, or so-called "ship-worm," although the latter term is a misnomer, since it really belongs to the order *Mollusca*. This creature is found in most seas, and works terrible havoc in piles, planks, and other woodwork immersed in water on our coasts. They occur in great numbers, and the creatures bore cylindrical holes—generally along the grain—these holes being either wholly or partially lined with calcareous substance.

The teredo varies from a few inches to three feet long, according to its species:

FIG. 10.—HARD WOOD PERFORATED BY WHITE ANTS DURING FORTY-EIGHT HOURS.

its anterior end, which is enlarged, carries a pair of shells, or valves, shaped like augurs. Its body is greyish white and its tail is forked, the head being rounded. It works round nails, knots, etc., and never enters a neighbouring burrow. The teredo avoids fresh water: it prefers clear salt water to that which is muddy.

Fig. 11 represents a piece of English oak (end grain) bored by teredo. The specimen was formerly part of a pile in Great Yarmouth pier. All kinds of timber are attacked, especially fir.

The only efficient protection from the teredo, which is applicable on a commercial scale, is to have all timber intended for submarine work thoroughly creosoted.

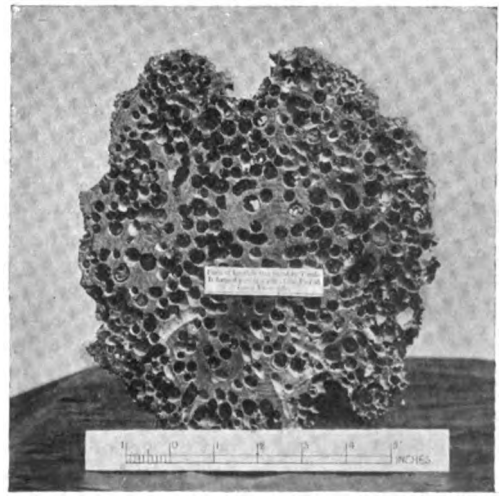

FIG. 11.—ENGLISH OAK, BORED BY TEREDO.

Figs. 7, 8, 9, 10 *and* 11 *are from photographs taken in the Natural History Museum, South Kensington, by kind permission of the authorities. The other illustrations are from photographs prepared by Mr. Busbridge, and sold as lantern slides by Messrs. Newton and Co.*

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ELECTRICITY FROM TOWNS' REFUSE.

By WALTER P. ADAMS, M.I.E.E., A.K.C.

THE immense improvement which has taken place in the public health during the last two generations is not sufficiently realised by the many residents in our towns and suburbs, who reap the advantage of the labours of sanitary reformers and medical men of the last century. From a study of the death-rate alone most interesting proofs are obtained of the advantage of cleanly living and surroundings. Two typical illustrations will suffice.

During the twenty-five years of office of the late Medical Officer of Health (the writer's father) in the London suburb of Barnes, the death-rate declined from seventeen to eleven per thousand, and now rarely exceeds twelve.

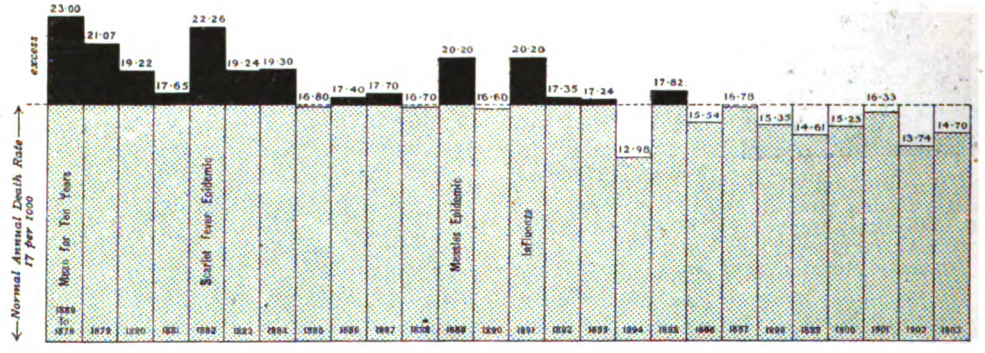

FIG. 1.—DIAGRAM SHOWING VARIATION IN THE DEATH RATE FOR ACCRINGTON, FROM 1879 TO 1903.

The graphic illustration of the declining death-rate in Accrington (Fig. 1) hardly needs explanation; and what is true of Barnes and Accrington is true of almost every large town and suburb in the kingdom.

There is no need to look very deep for the cause of this improvement; the main factors are efficient drainage and sewage disposal works, a regular and pure water supply, expert supervision of the conditions of living, (especially among the poor), and the intelligent application of the general principles of sanitary science under the direction of local medical officers of health.

A debt of gratitude, which is rarely acknowledged, is owing by the community at large to the noble army of medical officers of health, engineers, and town surveyors, by whom these improvements have been brought about.

One cause which has improved the public health is undoubtedly the systematic removal of household refuse and garbage.

The most usual method of disposing of this refuse, until recent years, was to tip it on to waste ground near the town—even to this day this barbarous method is in vogue in many places—and to send large masses in barges out to sea. Attempts are made, here and there, to turn its manuring qualities to account by spreading it on agricultural land, and, occasionally, its heat value is partially used in brick fields for burning the clay; but all these methods are open to objection, and only one really satisfactory way of effectually disposing of towns' waste exists, namely, its cremation in furnaces or "destructors."

This method is not only scientific, but the fuel value of the refuse in most localities is so great that, if utilised for raising steam for pumping water and sewage, generating electricity and driving machinery, the disposal of refuse in this manner becomes of commercial advantage to the public; and it is actually the case, in some favourable instances, that the fuel value exceeds the cost of destruction, so that a destructor becomes a profit-earning device to ratepayers.

The history of the development of the refuse destructor is most interesting. The advantage of burning the refuse in closed furnaces was recognised as early as the middle of the nineteenth century; but the first efforts to thus burn refuse were unsuccessful, and created a greater nuisance than the "green" refuse itself.

It was little thought in those early days

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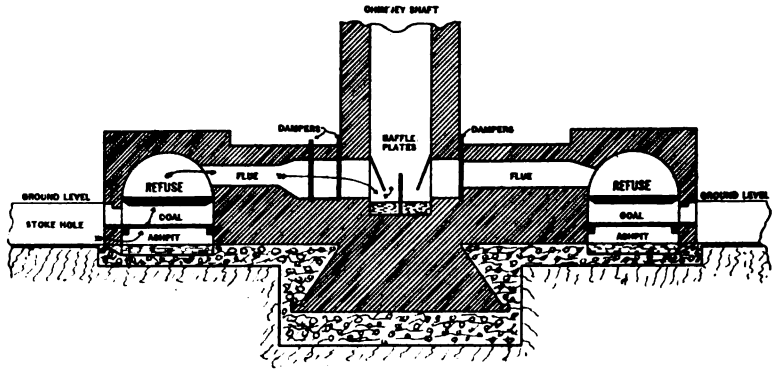

FIG. 2.—RICHMOND "BEE-HIVE" DESTRUCTOR.

that a self-supporting fire could be maintained with the refuse alone, and the "Beehive" is a type of several furnaces where it was attempted to assist the burning with a coal fire.

In Fig. 2 it will be seen that beneath the grate, upon which the refuse was deposited, a second grate was provided for burning coal. The heat from this coal first stewed the refuse above, and afterwards burnt it. The process of stewing, however, gave rise to such foul vapours, that some furnaces erected in Richmond in 1884 had to be shut down shortly after completion; besides the nuisance created, the cost of coal was considerable

The first destructor in which a self-supporting fire was maintained with the refuse alone, was invented and made by Mr. Alfred Fryer in 1876. A section is shown in Fig. 3.

The refuse was fed from the top on to an inclined hearth, called the "drying hearth," whence it was raked forward on to the furnace bars and burnt. The clinker was removed through doors in front of the furnace, and the hot furnace gases passed by side flues into the main flue below. The ash pit was open, and the necessary draft obtained by a high chimney. This furnace differs but little from several modern destructors, except that only natural draft from the chimney was used. In all modern destructors forced draft into a closed ash pit is used in addition to the natural chimney draft. This forced draft is produced, sometimes by steam jet blowers, and sometimes by fans driven either by steam engines or electric motors.

The Fryer destructor described above has been modified in many details, but the general principles are the same in most modern destructors. The better-known types are:—The Manlove Alliot, which is the Fryer with the addition of closed ash pit and forced draft. The Horsfall is not very different to the Manlove Alliot, except in some of the smaller details of construction. The "Stirling" and "Beaman and Deas" cells are also of similar type. The Meldrum "Simplex," and the Heanan and Froude are substantially different, and have the several cells opening from one to the other, so that the green gases from newly introduced refuse mix with the

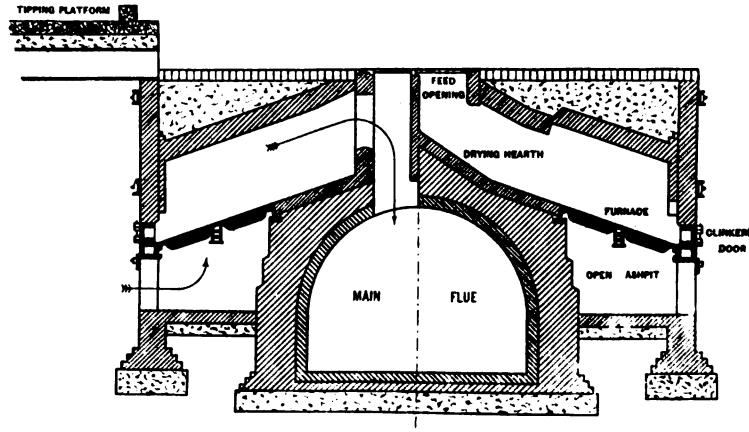

FIG. 3.—FRYER'S ORIGINAL DESTRUCTOR.

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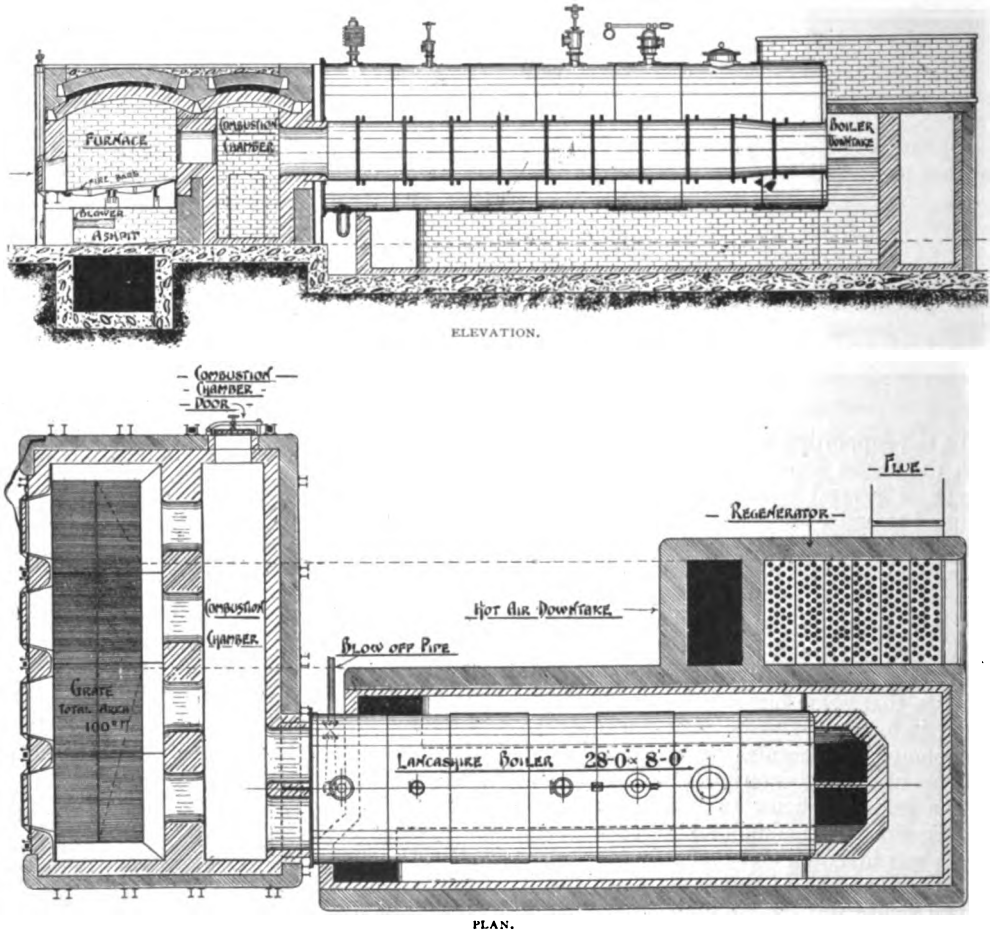

FIG. 4.—ELEVATION AND PLAN OF "SIMPLEX" DESTRUCTOR.

hotter gases from the cells where combustion is more complete.

I give illustrations (Figs. 4) of the Meldrum "Simplex," as the departure from the Fryer type is fairly considerable.

Although the furnace is practically continuous, each section or cell is fed separately, and each has its own closed ash pit and independently controlled forced draft.

The full development of the steam-raising value of refuse has only received close attention within the last five or six years or so, and even yet substantial improvements may be expected. The first application of steam raised from refuse to towns' purposes, on any extensive scale, was at Oldham, when, by chance, the Municipal Electricity Works and a Horsfall destructor were erected on the

TABLE I.—WATER EVAPORATED IN LONDON REFUSE DESTRUCTORS.

Name of Borough.	Date Destructor Installed.	Date of Test.	Tons of Refuse Burnt.	Duration of Test in hours.	Pounds of Steam Raised from 1 lb. of Refuse from and at 212°F.
Shoreditch . .	June, 1897	January, 1899	33·5	5	0·96
Stepney . . .	July, 1900	Jan. 12th, 1904	158	24	1·2
Fulham . . .	Dec., 1900	Dec. 17th, 1901	83·9	16	1·3
Hackney . .	April, 1902	Dec. 4th, 1902	133·75	19	1·415
Bermondsey .	Jan., 1902	Jan. 13th, 1903	18·8	7¼	1·657
Woolwich . .	April, 1903	Mar. 29th, 1904	63·25	24⅜	1·917

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same plot of ground. A boiler was erected with the destructor to supply steam for the forced draft, and for working the town's machinery. It was found, after a short time, that there was a considerable surplus available above that required for these purposes, and a steam main was carried into the adjoining electricity works. About this time it became increasingly obvious that the steam-raising power of refuse was much greater than had been anticipated, and, in 1898, the Combined Electricity and Destructor Works were erected at Shoreditch, with the definite purpose of using refuse-generated steam for producing electricity. Since then combined works have been erected at Stepney, Fulham, and Hackney, Bermondsey, and Woolwich, in the County of London, and some forty in the provinces. Besides supplying steam to electricity works, destructors in a number of towns are supplying steam for sewage and water pumping; but it is only since their combination with electricity works that attempts have been made to utilise to the full the heat-value of the refuse.

The principal improvements made recently are as follows:—(1) The provision of a combustion chamber immediately in front of the boiler where the gases from the different cells mix; this tends to render the temperature more uniform. (2) The blast for forced draft is now produced by electrically-driven fans, which are far more economical than steam jets or an auxiliary steam engine. It is also heated by being passed through a regenerator before it reaches the ash pit. This regenerator consists of a series of tubes placed in the flues behind the boilers, through which the cold air is drawn and raised to some 300° F. (3) Economisers are also placed in the flues for heating the boiler feed water. (4) The arrangements for charging the cells with new refuse, and also withdrawing the hot clinker from the furnaces, have been carefully modified to prevent the inrush of cold air to the flues during charging and clinkering. The joint result of these various improvements has been to increase substantially the quantity of steam raised per pound of refuse burnt. In the Shoreditch installation about 0·9 pound of steam is obtained per pound of refuse burnt, and in Table I. (page 268) the improvement will be readily observed. It is somewhat remarkable that in every one of these destructors the previous record obtained has been surpassed.

In different parts of the country the calorific value of the refuse varies considerably. In the neighbourhood of the coal fields it is generally richer in carbon than far away; and in some towns the quantity of trade refuse collected may be sufficient to affect either favourably or adversely the steam-raising value of the refuse.

The calorific value varies between 1,000 and 4,500 B. Th. Units per pound of refuse, while coal contains some 8,000 to 14,000 B. Th. Units per pound. Generally speaking, the incombustible matter in English refuse is from 25 to 35 per cent., while often as much as 35 per cent. of moisture is present. Under varying conditions it may be assumed that from one to three pounds of water may be evaporated per pound of refuse, and from six to ten pounds of water per pound of coal; the fuel-value of refuse may, therefore, be extremely well worth utilisation.

TABLE II.—WATER EVAPORATED IN SOME PROVINCIAL REFUSE DESTRUCTORS.

Name of Town.	Date Destructor Installed.	Short Test.				In Practice.			
		Date of Test.	Tons of Refuse Burnt.	Duration of Test in hours.	Pounds of Steam Raised from 1 lb. of Refuse from and at 212°F.	Period.	Time of Year.	Tons of Refuse Burnt.	Pounds of Steam Raised from 1 lb. of Refuse (actual).
Burnley . .	April, 1903	Dec. 14th, 1903	209	90	2·00	4 months	Ending June, 1904	2638	1·57
Nelson . .	Dec., 1900	April 25th, 1901	24·45	8	1·96	473½ hours	February, 1901	613·9	1·55
Darwen . .	—	—	104	48	1·55	1 year	Ending Mar. 31st, 1902	10,000	1·25
Partick . .	Feb., 1902	—	—	—	—	2 months	Ending Nov. 26th, 1904	2192	1·51

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In Table II. are given some steam-raising results on test, and over prolonged periods in some provincial towns.

The most interesting application of refuse-raised steam is, undoubtedly, in producing electricity. It has been well called a "Romance of Modern Engineering," and it seems little short of marvellous that waste material—all that is vile and noisome—should produce the most wonderful of Nature's forces that mankind has ever discovered and applied—a force that enters into almost every department of life and activity at the present day.

The quantity of electricity which can be generated from a given quantity of refuse depends—first, upon the fuel-value of the refuse; second, upon the efficiency of the destructor and steam-raising plant; third, upon the economical nature of the electricity generating plant; and last, upon the management of the works. I have dealt with the two first, and will now consider the third.

A modern steam dynamo of moderate size (say from 100 to 300 kilowatts capacity) will require from 25 to 35 pounds of steam per kilowatt hour. In addition, steam has to be supplied to boiler feed pumps, condensing plant, and other auxiliary machinery; and, in actual practice, the all-round water consumption, from year's end to year's end, in an electricity works may vary from 30 to 70 pounds, depending upon the efficiency of the plant, and, as stated before, also largely upon the management of the station—in other words, upon the "efficiency" of the engineer in charge and his staff.

The systematic measurement of water consumed in an electricity works is, unfortunately, generally considered to be a matter of secondary importance, and it is not easy to obtain data on this head. I have, however, figures from some of the London stations which will serve as a guide. At the Stepney Electricity Works (apart from the destructor) it is about 45 pounds per Board of Trade Unit (kilowatt hour) generated; at Fulham, 45 to 60; at Hackney, 27 to 35; this latter is discounted, to some extent, by the fact that the auxiliary machinery is electrically-driven, but allowing for this the average is, probably, about 35. The Hackney plant is the most up-to-date, so we might take, as a good standard, 40 pounds of water per unit generated.

TABLE III.—ELECTRICITY GENERATED FROM REFUSE, ON TEST.

Town.	Duration of Test.	Time of Year.	Refuse Burnt in Tons.	Units Generated.	Units per Ton of Refuse.
Stepney . . .	24 hours	January	158	6364	40·2
Fulham . . .	16 hours	December	84	5040	60
Hackney . . .	19 hours	December	133·7	7396	55·3
Woolwich . .	24·4 hours	March	63·25	3612	57·2
Gloucester . .	6 hours	November	9·1	720	79·9

Note.—In all of these tests, with the exception of Fulham, the plant was run non-condensing, and the water consumption was therefore high.

TABLE IV.—ELECTRICITY GENERATED FROM REFUSE, IN PRACTICE.

Town.	Period.	Year.	Tons of Refuse Burnt.	Units Generated Net.	Units per Ton of Refuse.	Pounds of Water per Unit Generated.
Stepney . . .	1 year	1903	43,326	1,386,210	32	72·5
Fulham . . .	1 year	1902–3	30,577	849,512	27·8	—
Hackney . .	1 year	1902–3	38,253	1,436,560	37·5	30
Bermondsey . .	1 year	1902–3	13,806	436,157	29·8	50
Nelson . . .	1 year	1902–3	6,658	266,000	40	105
Partick . . .	1 year	1902–3	13,500	398,862	29·6	55

(*To be continued.*)

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EXPANSION CURVES.

By G. C. TURNER, B.Sc.

LET it be required to determine the best values for the constants a, b, n in the equations

$$y = a + bx^n \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$x\,(y - a)^n = b \quad . \quad . \quad . \quad . \quad . \quad (2)$$
$$y = a + b\,10^{nx} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

on the supposition that in each case we have a table of values of x and y, and have reason to suppose that the corresponding pairs of values are connected by the corresponding law.

Since three constants have to be determined, it is clear that the ordinary straight line method is not of itself sufficient.

By plotting the values of x and y, and drawing a good curve to lie evenly amongst the points, we can easily find the constants from three properly chosen points.

If the curve really has the given equation, which three points are chosen is immaterial, provided the measurements can be made with sufficient accuracy.

(1) Choose three abscissæ x_1, x_2, x_3 in geometrical progression. $x_2 = kx_1$, $x_3 = k^2 x_1$, the number k being so chosen that most of the curve is utilised.

Denoting by y_1, y_2, y_3 the corresponding ordinates, we have

$$y_2 - y_1 = bx_1^n\,(k^n - 1)$$
$$y_3 - y_2 = bx_2^n\,(k^n - 1)$$
$$\therefore \frac{y_3 - y_2}{y_2 - y_1} = \left(\frac{x_2}{x_1}\right)^n = k^n$$
$$\therefore n = \left(\log \frac{y_3 - y_2}{y_2 - y_1}\right) \Big/ \log k$$

and n is determined.

Now plot y and x^n, which will give (approximately) a straight line if the law assumed is

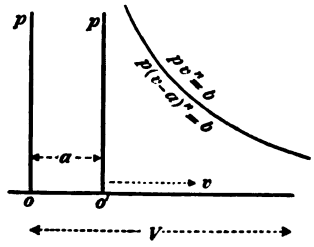

FIG. 1.

true. For this straight line, a is the intercept on the axis of y, and b is the tangent of the angle of slope.

(2) This equation is essentially the same as (1). It has an interesting application to the determination of the line of zero volume in the indicator diagram.

We know that the connection between the volume and pressure of the steam in the cylinder is of the form

$$pv^n = b,$$

but the diagram does not give the line from which the volumes are to be measured.

Draw any line Op (Fig. 1) from which volumes may be measured, and suppose $O'p$ the true zero volume line; then, referred to the axes $O'p$ and $O'v$, the equation to the expansion curve is

$$pv^n = b;$$

and referred to Op and OV it is

$$p(V - a)^n = b,$$

where a is the distance between Op and $O'p$. The last equation may be written in the form

$$V = a + b^{1/n}\,p^{-1/n}.$$

Choosing the p's in geometrical progression, we have, as in case (1)

$$-1/n = \log\left(\frac{V_3 - V_2}{V_2 - V_1}\right) \Big/ \log k$$

where

$$k = \frac{p_2}{p_1} = \frac{p_3}{p_2}.$$

On plotting V, and $p^{-1/n}$, a and $b^{1/n}$ are determined as before.

(3) The constants in the equation

$$y = a + b\,10^{nx}$$

can be found by a similar contrivance, only now the abscissæ are chosen in arithmetical progression, so that

$$x_2 = x_1 + k, \quad x_3 = x_2 + k.$$

Hence,

$$y_2 - y_1 = b(10^{n(x_1 + k)} - 10^{nx_1})$$
$$y_3 - y_2 = b(10^{n(x_2 + k)} - 10^{nx_2}).$$

Remembering that $10^{n(x_1 + k)} = 10^{nx_1} \times 10^{nk}$, we have

$$\frac{y_3 - y_2}{y_2 - y_1} = \frac{10^{nx_2}}{10^{nx_1}} = 10^{nk};$$

$$\therefore n = \frac{1}{k} \log \frac{y_3 - y_2}{y_2 - y_1}.$$

The values of a and b are now determined by plotting y and 10^{nx}

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THE FIBROUS CONSTITUENTS OF PAPER.

By CLAYTON BEADLE.

IT is important to ascertain exactly what effect is produced on machine and hand-made papers in regard to their physical qualities by the tub-sizing operations. For this purpose it is expedient, not only to find the strength and stretch of the waterleaf, etc., but to ascertain the conditions under which this was manufactured. With a view to throwing some light on this subject, in so far as hand-made papers are concerned, I was fortunate in enlisting the co-operation of one of the leading firms in this country, who carried out a series of trials at my suggestion. A number of sheets, which we shall call A, were made by the vatman: these received nominally only side shakes after they had been removed from the vat. A second batch of sheets, which we shall call B, received only backward and forward shakes, *i.e.*, in the short directions of the sheet. These sheets were both tub-sized, but not under similar conditions; consequently, B received a heavier sizing than A. We found on analysis that A contained 6·8 per cent. of gelatine, and B, 8·3 per cent. of gelatine. The trials were undertaken in May of last year. The makers of the paper tested some of the sheets before forwarding the same to me. Their tests on the sheets after sizing indicate that the ratios of the breaking lengths in the two directions are 82 per cent. for A, and 72 per cent. for B. This is just what we should expect from the manner in which the two papers were made. Thus the backward and forward shakes in B would tend to set the fibres in the same direction as that of the wave produced when the mould is taken out of the vat, whilst the side shakes with A would tend to set them at right angles to this direction. In other words, the condition under which B is made would tend to increase the stronger direction and decrease the weaker; and with B the tendency would be in the opposite direction, thus making the figure for A nearer to the 100 per cent. than that of B; but the difference between the two is not so great as one might expect.

When I received the sheets I laid them by for about a month, and then submitted them to a very thorough series of tests. The strength and elongation were tested in the case of A and B, both waterleaf and sized, both by the "fan" and ordinary methods. The conclusions to be arrived at as the results of these tests are extremely interesting, and, I venture to think, might be made use of commercially.

The "A" tests, for both sized and waterleaf, are shown in Fig. 1, the waterleaf by a thin line, the sized paper by a thick line. The bottom half of Fig. 1 gives the breaking strain at different angles, and the top half of the figure the percentage elongation at the same angles; the two sets of curves are shown together for comparison.

PAPER A, TESTED BY FAN METHOD.

Mean Strength.

Waterleaf paper . 10·01 lbs. per inch width.
Sized paper . . 20·04 lbs. per inch width.
Gain in strength due to the addition of 6·8 per cent. gelatine = 100 per cent.

Elongation.

Waterleaf . . . . . 4·77 per cent.
Sized paper . . . . . 5·84 per cent.

The gain in elongation due to sizing is therefore 22 per cent.

Comparing the two methods, *i.e.*, fan and the ordinary method, for testing strength:—

Mean Strength of Sized Paper A.

Ordinary method 20·39 lbs. per inch width.
Fan method . 20·04 lbs. per inch width.

Mean Elongation, Waterleaf A.

Ordinary method . . . 4·95 per cent.
Fan method . . . . . 4·77 per cent.

Mean Elongation, Sized Paper.

Ordinary method . . . 7·01 per cent.
Fan method . . . . . 6·84 per cent.

As regards the strength when pulled at different angles, on referring to Fig. 1 (thin line), it will be seen that this is almost constant in the waterleaf. This is what we might expect from the manner in which the paper was manipulated on the mould, but there are slight variations, and it will be noted that the ups and downs along the curves bear some resemblance to the ups and downs of the same paper after sizing

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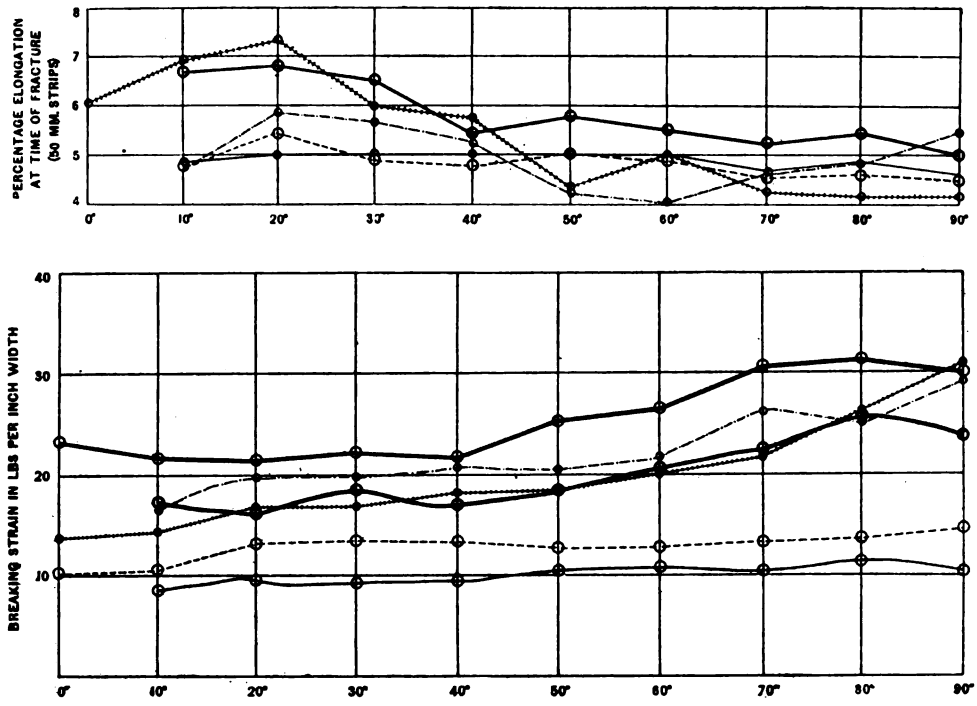

FIG. 1.—TO SHOW THE STRENGTH AND ELONGATION OF HAND-MADE AND MACHINE-MADE PAPERS, TESTED AT DIFFERENT ANGLES.

Hand-made shakes both ways. Half linen, half cotton. 25 lbs. L.P., gelatine, 7·8 per cent.
Cream wove (linen) machine-made bank. 10 lbs. L.P., gelatine sized.
Backward and forward shake waterleaf. Sized with 8·3 per cent. gelatine.
Backward and forward shake waterleaf. Unsized.
Hand-made "side to side shake" waterleaf. Sized with 6·8 per cent. gelatine.
Hand-made "side to side shake" waterleaf. Unsized.

(thick line). This might be a mere coincidence, but the same is shown in the case of paper B for waterleaf and sized (compare broken line with dot and dash line): in this latter case it is more marked. The natural inference from these results is that, although a hard made paper can under ordinary conditions be prepared in the waterleaf, of nearly uniform strengths at different angles, yet there are slight irregularities, showing a sort of latent disposition to irregularity in strength, which is subsequently very much enhanced by sizing; the extent of the sizing determines the amount of the irregularity.

With regard to the elongation of the above-mentioned papers, shown on top half of Fig. 1, this remains fairly constant with waterleaf A, but after sizing the elongation becomes far greater in the weakest direction, and is only to a small extent increased in the strongest direction. If we exclude the determination made at angle 40, which may have been due to some irregularity in that particular sheet, the two curves show a certain amount of correspondence. But in the case of B the stretch in the state of waterleaf and sized papers shows no correspondence whatever.

The paper with backward and forward shake does not show as much difference in strength at different angles as with ordinary hand-made paper in the waterleaf, but after sizing (8·3 per cent. gelatine) the wavy lines are much accentuated. One thing appears to be evident, namely, that it is impossible under ordinary conditions of working to overcome the effects of the wave made by lifting the mould out of the vat by any number of subsequent counteracting side shakes. The percentage elongation at time of fracture with the A or side shake waterleaf remains almost constant at the different angles of pull, but after sizing the elongation is considerably increased at the low angle test. After the angle of 50° it remains fairly constant, but considerably above that of the waterleaf.

The percentage elongation of the backward

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and forward shake waterleaf B is fairly constant at the different angles, although slightly greater at one near the sideway direction. After sizing the same paper shows greater variation, being greatest in the sideways direction. The study of these curves will enable general conclusions to be formed, although we must guard against those depending on slight variations, which, although true in individual cases, may not be so in general. The double line curves show the normal curve for best hand-made tub-sized paper as ordinarily made when tested for strength at different angles. It is worthy of note that the maximum and minimum strengths are 10 per cent. away from the two sides of the deckle edge, instead of exactly corresponding with them, as is generally supposed. For the purpose of comparison with the rest, the strength and elongation at different angles of a cream wove linen machine-made bank, 10 lbs. large post, tub-sized, is given. This shows that the elongation diminishes and the strength increases as the pull approaches the machine direction, but that the elongation curve shows waviness, up and down, whereas the strength curve is fairly regular.

(*To be continued.*)

THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C.,
Chemical Engineer and Consulting Chemist, Manchester.

Fractional Distillation.

FRACTIONAL distillation is a process for separating liquids which boil at different temperatures. The general view is that, at the boiling point of a mixture of liquids, the most volatile constituent evaporates first, and carries with it only a certain quantity of the less volatile constituents. If, therefore, the part which passes over is cooled, a product is obtained which consists chiefly of the volatile parts of the mixture. As the distillation proceeds the residue in the retort will gradually be freed from more volatile substances, and its boiling point will accordingly be raised. It is impossible to separate some mixtures by fractionating: cases occur where the constituents, at a certain point of the distillation, form groups which may be considered as combinations; and in this case, although the distillate will pass over at a fixed temperature, it will not be a pure compound, but a mixture or combination of fixed boiling point. Thus a mixture of 8 per cent. of water and 92 per cent. of alcohol cannot be separated by fractionating. On boiling a weak aqueous solution of hydrochloric acid, water will be given off until the residual product contains a mixture of 20 per cent. of HCl and 80 per cent. H_2O; and on boiling a strong solution of hydrochloric acid in water, hydrochloric acid gas will be given off until the remainder in the still is again composed of 20 per cent. of hydrochloric acid and 80 per cent. water; in both cases the boiling point will be found to be 110°C.

The laboratory apparatus used for fractionating consists of a flask provided with a fractionating tube connected with a Liebig condenser. Many different designs of these fractionating tubes have been proposed, though all are based on the principle of opposing a certain amount of resistance to the vapour passing through them, and of increasing the cooling surface, and thus effecting the condensation of the higher boiling vapours, whilst the lower boiling vapours pass on through a Liebig condenser. On a large scale the principle is exactly the same. The mixture of the liquids to be separated is placed in a still of suitable shape, made of a material that will not be attacked by the substance which has to be manipulated. It is sometimes most difficult to find a suitable substance from which to construct the still: the most varied materials are used, including cast iron, wrought iron, copper, silver, lead, enamelled iron, earthenware, and even glass.

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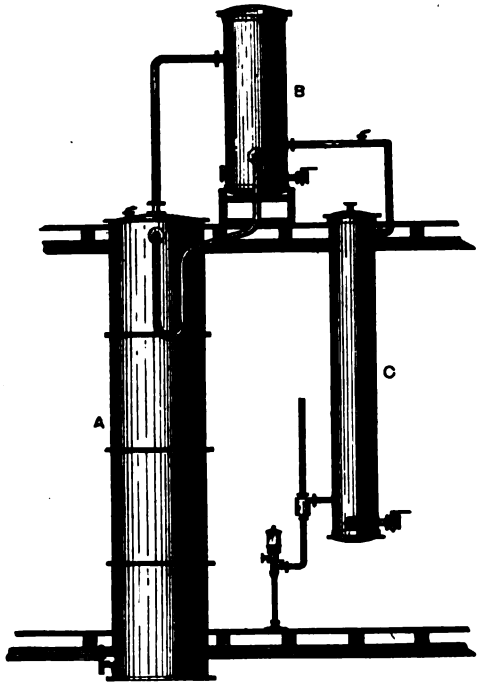

FIG. 15.—TO SHOW GENERAL ARRANGEMENT OF FRACTIONATING PLANT.

According to the nature of the substances, and the temperature they require for separation, the still may be heated by open fire, by steam, or by hot water ; wherever inflammable liquids, which give off vapours at comparatively low temperatures, have to be treated, it is a fixed rule that no open fire must be used. Fig. 15 shows the general arrangement of a fractionating plant.

The vapours which come from the still pass through a separator A, which corresponds to the fractionating tube used in the laboratory model. This separator generally consists of a metal tube A, which may be divided horizontally into a number of compartments by sieves (as shown in Fig. 17), or by plates provided with lutes covered by bells (as shown in Fig. 16). Tubes are provided at the sides, so that condensed liquid may run back into the still. The distillation is regulated in such a manner that, if the separator is kept at the proper temperature, only vapours pass from it into the vessel B. This vessel really represents the Liebig condenser of the laboratory apparatus, but is inverted so that whatever condenses in it goes back in the separator, while the lighter constituents pass on into the receiver C, where they are completely condensed. It may not be unnecessary to point out that in a system of this kind the separation of the constituents takes place not only in the still, but to a great extent also in the separator ; and that the success of the operation depends largely upon the proper management of the cooler B, which regulates the quantity of liquid that runs back into the separator.

We have only been able to touch lightly on the very important cases in which heat is applied in chemical operations, and have so far altogether omitted its application for purposes of drying, fusing, and melting, which should naturally follow in this place. In order, however, to give a little variety to the subject, we prefer to leave that part to a future occasion, and to introduce now a subject which will enable us to show how it is sometimes necessary to introduce methods of procedure in practical work which differ in principle from those adopted in the construction of laboratory apparatus. Such a subject is presented in the apparatus used for filtering.

THE FUNNEL AND ITS TECHNICAL EQUIVALENTS.

Many operations in the laboratory—in fact, nearly all operations connected with quantitative gravimetric analysis—depend upon the production of insoluble or slightly soluble precipitates, which by various means are separated from the liquid in which they are suspended. If the precipitate is suspended in a large amount of liquid, and if it settles

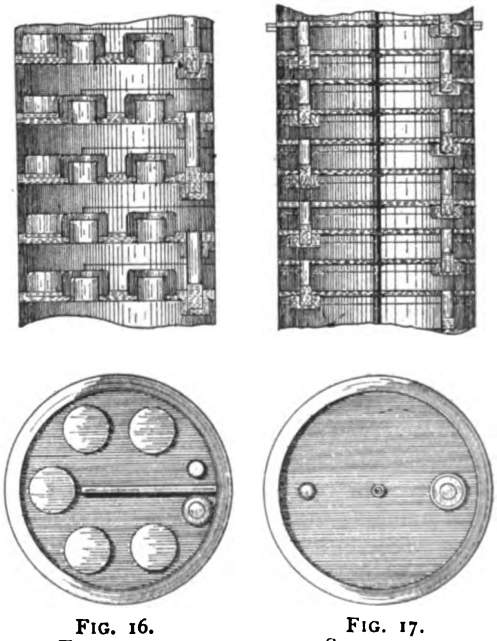

FIG. 16. FIG. 17.
TWO DIFFERENT TYPES OF SEPARATOR.

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well, part of the liquid may be poured from it. The same would apply on a large scale; but in the case where, in the laboratory, it would be necessary to pour the liquid off, on a large scale taps could be arranged in cisterns at convenient distances, which on being opened would let off the clear liquid and leave the precipitate undisturbed. When the precipitate is easily disturbed, it is usual, in laboratory work, to use a syphon made of glass tubing for drawing off the clear liquid. On a large scale, except in special cases, it is not usual to use a glass syphon: but according to the nature of the liquid, syphons may be made from lead or copper tubing, and they may be constructed to work automatically, by making the short end of the syphon which dips into the liquid of a flexible material connected to a float; it will then lower itself automatically as the level of the liquid descends.

In the laboratory it will generally be found more convenient to effect the separation of the precipitate from the liquid by filtering the mixture through filter paper placed in a funnel. Where comparatively small quantities have to be dealt with on a large scale, the filter paper may be replaced by bags made of cotton, woollen, or linen cloth, the coarseness or fineness of which will depend upon the nature of the precipitate. The choice of suitable filter cloth is of great importance, and comparative tests should be made in the laboratory before deciding which kind of cloth to use in the works.

In order to accelerate filtration, the laboratory chemist often filters under diminished pressure, by fixing the funnel into a flask which is connected with a Bunsen pump, thus drawing the filtrate into the flask. This may be done on a large scale in an apparatus which is shown in Fig. 18.

The liquid enters the apparatus A at B, and C being connected with a vacuum pump, the space D will become exhausted, and the liquid will be drawn through the filter cloth which is placed on the false bottom E, leaving the residue on this.

It will occur to the reader that this apparatus might be used in a different way. Suppose, instead of drawing the air through by creating a partial vacuum, we were to pump air into the top of the apparatus; we could then force the liquid at increased pressure through the filter cloth instead of drawing it through by means of a vacuum. This is an operation which is not performed in the laboratory because it would not only be difficult to construct suitable apparatus, but because it would not offer any particular advantage over filtering in a vacuum. On a large scale, however, it is different. Working in a vacuum means working in a closed system, and thus adding to the expense of the installation. Moreover, each time the apparatus

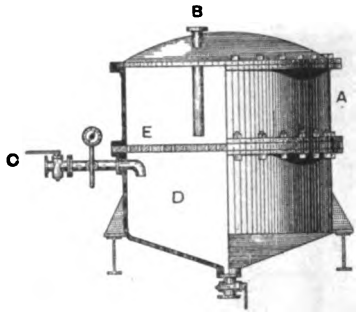

FIG. 18.—APPARATUS FOR FILTERING UNDER DIMINISHED PRESSURE.

is emptied the vacuum must be broken, and a loss in labour and fuel incurred. It is, therefore, cheaper to work under pressure than to work in a vacuum; and for this reason filtering under pressure has become one of the most important accessories to chemical work. The apparatus which is used for this purpose is called a "filter-press," and consists, broadly speaking, of a set of chambers separated by filter-cloths. The mixture of liquid and precipitate is forced by means of a pump, compressed air, or by natural gravitation, into the press.

There are two kinds of filter-presses—chamber presses and frame presses. In the chamber presses the mixture of liquid and solid matter is introduced through a channel which runs through the centre of the press. The filter-cloth hangs from the top of the chamber, so as to cover each side of it, and has an opening cut into its centre, so that it can be screwed tight into the channel of the chamber. On screwing the press together, it is evident that the two filter-cloths will touch each other, and the chances of obtaining a water-tight system are, therefore, increased. The sides of the chambers project in such manner that the cake of separated solid matter collects in the space formed by the projections, and on opening the press, the pressed mass falls out automatically. In frame presses the cake is formed in frames which are separated by filter-cloth, with openings at the side through which the liquid mixture is introduced. On opening the press, the cake remains in the frame, which can be lifted out and emptied. Fig. 19 shows a drawing of a chamber filter-press.

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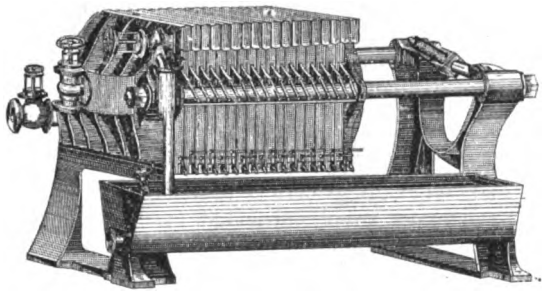

FIG. 19.—CHAMBER FILTER PRESS.

Whatever the construction of the press may be, it is provided with solid end pieces, one of which is stationary, and the other movable by means of a screw or lever or other mechanical arrangement. The most usual materials of which presses are made are iron and wood; but for special purposes they may be lined, in those parts which are exposed to the liquid, with lead, ebonite, or any other resisting material. As stated before, they may be fed either by natural gravitation, or by means of pumps or compressed air, and arrangements are generally provided for washing the cakes free from the original liquor. As the presses may be worked at almost any pressure, it is evident that care must be taken in ascertaining the pressure at which the required substance will filter best. Thus, with very slimy substances great pressure would only have the effect of depositing a thin film on the filter-cloth; this would become stopped up, and further filtration would cease. The manufacture of filter-presses has become a speciality with several well-known firms of engineers, who construct them in many varieties, to suit special purposes. They may be obtained suitable for dealing with substances which, during filtration, have to be kept at a raised temperature, so as not to crystallise out; or have to be kept at a low temperature, so as not to melt. These purposes are generally effected by channels being provided in the chambers through which steam, or hot or cold water may be passed.

Besides being used for filtering purposes, a funnel is often used in the laboratory for draining crystals or similar substances free from part of their moisture or mother-liquor. Sometimes the student in the laboratory will effect this purpose quicker by putting the crystals into a little bag attached to a string, and swinging the bag round for some time. In doing this he practically does what a centrifugal machine does on a large scale. It is well known that when a body is compelled to move in a curved line, say a circle, it has a tendency to leave the curve at a tangent—that is, to get away from the centre of curvature. The natural consequence is that it presses against the sides of the vessel in which it is made to move, and which prevents it from going into space. This is known as the centrifugal force of a body, and it is proportionate to the square of the velocity of the body.

A centrifugal machine, or a hydro-extractor as it is often called, is based on this principle; that represented in Fig. 20 consists of a cage A, made to revolve at great velocity in a solid frame B which surrounds it; the latter is supplied with an aperture C through which any liquid may drain. The cage is made of sheet copper or iron, and perforated with holes or with slits. A centrifugal machine may be over-driven or under-driven—that is, the arrangement by which it is coupled up to the engine may be placed either below or above the cage. If crystals containing moisture are placed in the cage, and the machine is set in motion, the crystals are thrown against the sides of the cage, and the water will be forced through the openings, so as to leave the crystals comparatively dry. When the mass which is to be dried is of a very fine texture, so that it would go through the openings in the cage, it is necessary to place a filter bag within the cage, and on this the crystals or other materials are deposited. In this case it is particularly necessary to bear in mind that with double velocity the pressure against the sides is quadrupled; with triple velocity it is rendered nine times as great, and so on; thus it is

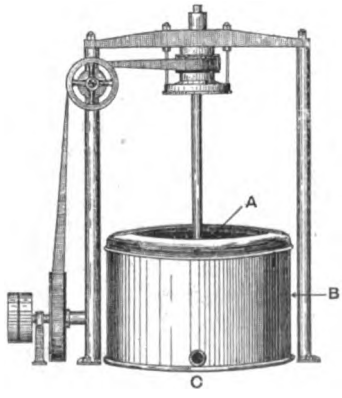

FIG. 20.—CENTRIFUGAL HYDRO-EXTRACTOR.

quite possible that with a centrifugal machine revolving at a great speed we might get worse results than with a machine revolving at a lower speed, as under a high centrifugal

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force the filter-cloth or the interstices of the cage may become stopped up. The fact that the centrifugal force increases proportionately to the square of the velocity adds to the danger of the machine. Care must be taken that the mass in the cage is evenly distributed; hydro-extractors are sometimes provided with an arrangement by which any unevenness of distribution is automatically counterbalanced.

It follows, of course, that the centrifugal machine can also be used for filtering or drying precipitates; in most cases, however, it will be found that a filter-press is more suitable for this purpose, as in this case it is easier to wash the precipitate with a minimum quantity of water or liquid than in a centrifugal machine. When dealing with precipitates it is always necessary to use a filter-cloth in the centrifugal machine, and it is then particularly necessary to see that the velocity at which the machine works is suited to the material, and is not so great that the pores of the filter will become stopped up.

It is often found necessary, in the laboratory, to filter substances through sand, asbestos, glass or similar material, which in that case is placed at the bottom of the funnel. On a large scale similar arrangements are frequently used, particularly for clearing water or trade effluents, and in sewage works. In such installations large cisterns are generally built in the ground with brick, concrete, or similar material. These may contain false bottoms, or may be simply provided at the bottom with channels for letting off the clear filtered liquor. Further, they often have arrangements for distributing the original liquor evenly over the top of the tank. These cisterns are partially or wholly filled with sand, coke, coal, broken bricks or similar material.

The processes of filtering are of great importance, and require considerable practical experience. They belong, unfortunately, to those parts of chemical engineering in which theory can be of but little use, except in those points which we have indicated. They present, however, an interesting example of processes which, though impracticable in the laboratory, can be carried out successfully on a large scale.

FORMIC ALDEHYDE IN THE AIR.

H. Henriet, who lately detected formic aldehyde in the air, has determined the proportion to be between 2 and 6 grammes in 100 cubic metres. This proportion is higher than the normal amount of ozone, which is from 1 to 3 milligrammes only. Filtered air is passed over mercuric oxide heated to 250°, and the total carbonic acid gas thus obtained, determined. The excess of this amount over the amount of carbonic acid in the same volume of air not passed over heated mercuric oxide is due to oxidation of the formic aldehyde. Minute quantities of formic acid are also present. (Comptes Rend., 138, 1, 272.)

A. Trillat finds formaldehyde invariably present in the products of combustion and smoke from burning organic matter, as wood, paper, pure cellulose, rubber and tobacco, in proportions varying between 1 : 1,000 and 1 : 10,000. Even a simple hydrocarbon like benzol gives an appreciable quantity, 1 : 120,000 of its weight when burnt. Toluene gives 1 : 80,000, and xylene 1 : 40,000. Although the amount formed may vary with the conditions under which the organic matter is consumed, formaldehyde is a constant and normal constituent of the combustion products. Probably the air of smoky manufacturing towns will prove to be richer in formaldehyde than that of ordinary localities. (138, 1, 611.)

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A VARIABLE SPEED GEAR.

Giving all Speeds from Zero to a Maximum.

WITHIN the last few years numerous speed gears have been put on the market: these have all been alike in one respect, *viz.*, that they give only a limited number of definite speeds; and, indeed, it has generally been believed that a speed gear characterised by a direct drive, and yet capable of continuous adjustment for all speeds, was an impossibility. The "Newman" speed gear, however, successfully accomplishes this result, any speed between zero and a certain maximum value being obtainable by its use. This gear is represented diagrammatically in Fig. 1. The central pinion G is fixed; round this revolve four planet-pinions which rotate about studs fixed to the gear case, which in its turn is rigidly connected with the variable speed shaft. Each planet-pinion comprises two separate parts—an outer annulus with external teeth, and an inner disc rotating freely on the stud fixed to the gear case. The only connection between the inner disc and the outer toothed annulus is effected by a roller clutch arrangement. On the periphery of the disc are four slots containing rollers; each slot on one side is not quite so deep as the diameter of the contained roller, while on the other side it is somewhat deeper than the diameter of the roller. The slots are shown black in Fig. 1. If a disc is rotated in a clockwise direction at a speed greater than that of its surrounding annulus, the roller rolls into the narrower part of the slot, and the disc and annulus run solid; if the speed of a disc is less than that of the annulus, or if the disc is rotated in an anti-clockwise direction, the roller rolls into the deeper part of the slot, and the disc and annulus become free of each other.

Let us now suppose that one of the discs shown in Fig. 1 is rotated backwards and forwards through a small angle; during the small clockwise rotation the roller clutch is operative, and the annulus is forced to rotate, and consequently rolls through a small distance about the central pinion G; in doing so, it carries with it the gear case and the other planet-pinions. During the small anti-clockwise rotation, the roller clutch releases the annulus, so that while the disc returns to its original position the annulus does not follow it. It is thus clear that

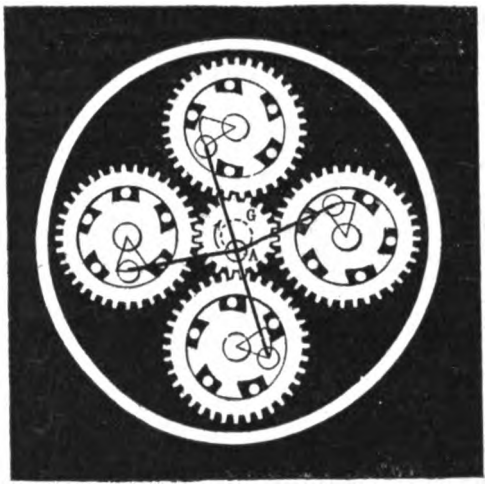

FIG. 1.—"NEWMAN" SPEED GEAR.

successive small backward and forward rotations of one of the discs will cause the gear case, and with it the variable speed shaft, to rotate in a clockwise direction. The way in which the small backward and forward rotations of the discs are produced is as follows:—

At the end of the constant speed shaft is an excentric stud, shown in section at A (Fig. 1). This stud, of course, is in no way connected with the fixed pinion G, but revolves over this in the dotted circle shown. The excentric stud is joined, by means of four connecting rods, to pins in the central discs of the four planet-pinions; thus, during one rotation of the constant speed shaft, each disc will effect a forward and backward motion, and the surrounding annulus will be forced to roll a certain distance around the central pinion G. The positions of the connecting rods (represented by thick lines in Fig. 1) are such that, as the roller clutch of one planet-pinion disengages, that of the next pinion engages, and consequently the gear case rotates continuously at a rate dependent on the excentricity of the driving stud, which can be varied at will. Let the excentricity of the driving stud be such that the throw of a particular connecting rod is equivalent to a rotation of n teeth of the connected planet-pinion; then if the central fixed pinion has T teeth, it can be proved, by an application of

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the principle explained on p. 230, that the variable speed shaft will turn at a rate equal to $\{4n(T + 4n)\}$ of that at which the constant speed shaft turns. The proof alluded to is as follows:—

Let us suppose that the gear case and variable speed shaft are held stationary, the central pinion G being free to rotate; then, while the constant speed shaft completes one rotation, carrying the driving stud A with it, *each* planet-pinion will have rotated in a clockwise direction through n teeth, and will have caused the central pinion to rotate through (n/T) of a complete rotation; thus the central pinion will have altogether rotated through $(4n/T)$ teeth in an anti-clockwise direction. Let us now bring the central pinion A to its original position by rotating the whole of the gear as a solid body through $(4n/T)$ of a clockwise rotation; then the driving stud A and constant speed shaft will have rotated through $\{1 + (4n/T)\}$ turns, and the gear case will have rotated through $(4n/T)$ turns; therefore the ratio

$$\frac{\text{Speed of variable speed shaft}}{\text{Speed of constant speed shaft}} = \frac{4n}{T + 4n}.$$

The Newman Speed Gear is made by Messrs. Johnson & Phillips, of Charlton, Kent. It was exhibited at the Automobile Exhibition at Olympia, where it attracted much attention. When it is fitted to a motor car, the latter can be made to crawl along at the smallest conceivable speed, or the speed can be gradually increased to a maximum without any discontinuity or shock.

A POSSIBLE GAS ENGINE ECONOMY.

AMONG the many valuable papers lately read before the Sixth International Electrical Congress at St. Louis, was one by Mr. W. L. R. Emmet, on the Effect of Steam Turbines on Central Station Practice. Apart from its main points, this paper is particularly interesting, as in it Mr. Emmet draws attention to what might prove to be a very valuable economy in gas engine operation. The idea he brings forward is old, and has been to a certain extent discounted in the past: with recent improvements in prime movers its possibilities have, however, increased, and at any rate it provides food for profitable thought.

As is well known, the exhaust gases of an internal combustion engine are of high temperature, and in the ordinary way represent a dead thermal loss. In like manner, the cooling jacket water absorbs much heat, which passes away and adds to this inefficiency. In view of these two points, it has been suggested that the water should be conducted to a special boiler fired by the hot exhaust gases, and that the low-pressure steam generated should be used to develop power in a suitable prime mover.

Mr. Emmet suggests the steam turbine for this purpose, and considers it possible in this way to obtain an increase in the available work of 30 per cent. Others who have conducted investigations in this field have never claimed quite such a favourable result, 15 to 20 per cent. having, so far, been the most optimistic estimate.

Another, and upon the face of it a better suggestion, is to couple the low-pressure steam engine direct to the gas engine shaft, thus making one set of the two, economising floor space, and compensating to a certain extent for the irregular motion of the former and main engine.

There appears to be no evidence that anything has been attempted practically in this direction, and, no doubt, the complexity of the problem is the chief cause. It would seem, however, that such a scheme is far from being utterly impracticable; and perhaps the renewed publicity given to it in Mr. Emmet's paper, coupled with the alluring nature of the idea, may result in some form of practical trial, or at least a thorough investigation into its possibilities.

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REVIEWS.

Mechanism. By S. Dunkerley, M.Sc., A.M.I.C.E., M.I.M.E., Professor of Applied Mechanics in the Royal Naval College, Greenwich. pp. viii. + 408, with 416 illustrations. (London: Longmans, Green & Co., 1905). Price 9*s*. net.

The subject-matter of this book treats of pure mechanism, or the kinematics of machines. The works of Willis, Rankine, and Reuleaux treat of mechanism from a philosophical standpoint, and therefore the author justly considered it unnecessary to dwell on this aspect of the subject. On the other hand, a treatise on mechanism, written from the practical point of view, has been badly needed, and Professor Dunkerley's book is just of the kind required.

An elementary descriptive chapter, dealing with machine tools and mechanisms used for special purposes, has been added. This will doubtless be welcomed, the more so as the author treats this, in common with other parts of the subject, with an engaging freshness and vigour. The remaining chapters include a full discussion of straight line motions, indicator mechanisms, quick return notions, couplings, velocity diagrams, approximate solutions to link motions and radial valve gears, acceleration diagrams, toothed wheels, non-circular wheels, cams, and machines for cutting teeth. A number of numerical examples are added at the end of the book.

The book is printed on good paper, and the printing and illustrations are excellent. The occasional use of mathematics was unavoidable, but that used should give no trouble to anyone with very moderate mathematical attainments. Some of the most difficult problems that present themselves to the engineer are those connected with the forms of teeth; these problems are fully discussed in a most able manner, and Professor Hele-Shaw's development of Willis's mechanical method of solution should prove most useful. In dealing with velocity and acceleration diagrams, Professor R. H. Smith's methods have been used with advantage. Approximate methods of solution of various problems come in for a due share of notice: this is a valuable feature of the book, for it may safely be said that, in the mathematical work of a practical engineer, approximations play a more important part than exact calculations, and the college training of engineers in mathematics is too often rendered almost valueless by ignoring this. A useful index has been added. Altogether, Professor Dunkerley has produced a book of which it is impossible to speak too highly.

Manual of Chemical Analysis, as applied to the Assay of Fuels, Ores, Metals, Alloys, Salts, and other Mineral Products. By Eugène Prost, D.Sc., of the University of Liège. Translated from the original by **J. Cruikshank Smith, B.Sc., F.C.S.** pp. viii. + 300, with 45 illustrations. (London: Maclaren & Sons, 1904). Price 12*s*. 6*d*. net.

This book deals, in a clear and succinct manner, with the chemical analysis of the various ores, minerals, metals and alloys met with in the chemical and metallurgical industries, and should prove of great use to chemists, analysts, assayers, engineers and others interested in the analysis and valuation of industrial products of mineral origin. Details of manipulation are given, together with precautions which ought to be observed in connection with the various processes described. The metric system of weights and measures, and the centigrade scale of temperature, are used throughout the book, except in a few special cases which are indicated.

The processes described are confined to those which Dr. Prost has found from experience to lead to satisfactory results, except in the case of processes which have been communicated to the author by experienced chemists in charge of important laboratories. By a constant endeavour to avoid unnecessary repetitions an enormous amount of information has been crowded into a small space; the succinctness of the descriptions greatly adds to their value. The translator has done his work well, and a very full and useful index has been added.

Machine Tools and Workshop Practice for Engineering Students and Apprentices. By Alfred Parr, Instructor in Fitting and Machine Shop, University College, Nottingham; **with an Introduction by William Robinson,** M.E., M.I.C.E., Professor of Engineering in the same college. pp. xvi. + 444, with 510 illustrations. (London: Longmans, Green & Co., 1905.) Price 10*s*. 6*d*. net.

The aim of this book is to explain, in a connected form, the construction and use of machine tools; the experience gained by the author has placed him in a position to give adequate instruction for the use of students attending technical colleges, and apprentices or beginners in the machine shop. The book covers a large range of subjects, and cannot fail to be of use to

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the practical worker; it will help him to study and understand the use of the machine tools he uses, to judge of the most efficient tools for a given kind of work, and further to appreciate the most approved methods of organising and doing work.

In recent years, the necessity for division of labour has led to the introduction of automatic machines, with the most favourable results. Although these machines are worked by unskilled labour, they have nevertheless called into being a class of specially-skilled artisans to make the cutting tools required. In hand work, or in the older types of power-driven lathes and similar machines, an indifferent tool may be made, by the exercise of judgment and resource, to do good work; but the essential need of an automatic machine is that skill and knowledge must not be required in its use, and therefore the exercise of these qualities devolves on the designer of the machine and the maker of the necessary cutting tools. This aspect of the subject is very ably dealt with in the book before us. The first chapter is devoted to measurement, a subject which obviously demands first notice. The subsequent chapters contain descriptions of lining out tools and processes, materials, drills and drilling machinery, turret lathes, treadle and power lathes, lathe appliances, boring machines, lathe work, grinding machines; sawing, planing, shaping, and slotting machines; milling machines, gear cutters, cutting tools and their use; fitting and erecting work, forge shop tools, hydraulic machine tools, the transmission of power, and methods of working.

The book is splendidly illustrated, and is provided with an index.

Electricity Control: a Treatise on Electric Switchgear and Systems of Electric Transmission. By Leonard Andrews, A.M.I.C.E., M.I.E.E. pp. xvi. + 231, with 2 plates and 204 figures in the text. (London: Charles Griffin & Co., 1904). Price 12*s.* 6*d.* net.

Amongst the imposing array of books which have been written to meet the wants of the electrical engineer, this book stands alone in many respects. In the first place, it deals with a detail of electrical engineering practice, and that a most important one, to which due attention has been given only during recent times, and therefore the references to this subject in most text-books are somewhat casual. The author very aptly compares the switchboard with the nerve-centre of a human being; and just as an inconsiderable lesion in the brain may produce disturbance or paralysis in the whole living organism, so any defect in switchboard construction is sure, sooner or later, to make itself felt throughout the whole area fed by an electrical supply system. In the second place, the author has wisely described many systems which have been abandoned, giving the reasons for the desuetude into which they have fallen. This is a valuable feature, and, if generally adopted in text-books, would prevent much waste of time in inventing devices which have already been proved to be worthless; in addition, some devices, which failed on account of specific difficulties which arose in their use, might possibly be utilised under different and more favourable conditions.

Successive chapters treat of the general principles of switchboard design, constructional details, circuit breakers (including switches operated automatically and by hand), alternating reverse current devices, arrangement of 'bus bars and apparatus for parallel running, controlling apparatus for high and low tension systems, examples of complete installations, and long-distance transmission schemes. The author's style is clear and forcible, the letterpress is well printed on good paper, and the illustrations are excellently reproduced. This is obviously a book which should form part of the library of every electrical engineer.

Notes on Building Construction, arranged to meet the requirements of the syllabus of the Board of Education, South Kensington. New and revised edition. Part I., pp. xx. + 346, with 695 illustrations. Part II., pp. xviii. + 422, with 496 illustrations. (London: Longmans, Green & Co., 1904.) Price 10*s.* 6*d.* net for each part.

The builder of to-day requires a much more extensive knowledge than sufficed for his predecessors. Not only has the keen competition of recent years called for the adoption of methods which are at once economical and efficient, but more attention must be paid to details such as drainage; moreover the efficient heating, lighting, and ventilation of a building must often be taken into consideration. The books before us should prove of the utmost value to all those whose duties are connected with the building of houses, for they give just the information required, while yet their scope embraces many important subjects which are not infrequently omitted from books of a similar description. The books are well printed and illustrated, and everything possible has been done to render them as attractive and useful as possible.

The first volume is devoted to walls and arches, brickwork, masonry, carpentry (including joists and fastenings, floors, timber beams, curved ribs and trussed girders, partitions, centres, and timber roofs), roof covering, slating, plumber's work, steel and iron girders, riveting, and steel and iron roofs. The subjects considered in the second volume are:—Foundations, excavations, shoring, scaffolding, plumbing and sanitation, joinery, stairs, fireproof floors, plasterer's work, painting, paper-hanging and glazing, heating and ventilating buildings, electric and gas lighting, materials, and stresses in structures. In a future edition it would be advisable to give some information on the setting of kitchen ranges and other similar subjects; these processes are apparently of so simple a character that as a general rule no thought is devoted to them, with the consequence that a large proportion of the houses built in recent years are fitted with ranges which are most inefficient in their action, mostly due to the casual way in which they have been fitted in their places.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

MOLECULAR STRUCTURE.—Assuming that the hydrogen molecule contains an even number of atoms, give reasons for the generally accepted view that the number is 2, and not 4, 6, etc.

(1) In accordance with Avogadro's hypothesis the molecules of all gases occupy the same effectual space under similar conditions of temperature and pressure. A large number of hydrogen compounds are known, which are either gaseous or may be rendered gaseous; of these it is highly probable that *one* at least contains only one atom of hydrogen. Nevertheless, if such a weight of any known substance be taken as contains 1 gram of hydrogen in the gaseous condition, it is in no case found to occupy more than twice the volume of 1 gram of free hydrogen at the same temperature and pressure. In other words, no substance is known, the molecule of which contains less than half the number of atoms present in a molecule of hydrogen.

(2) In a substance such as methane, it is found that the hydrogen may be replaced in several successive stages (in this case four), and the amount replaced at each successive step is the same. Now a comparison of the density of methane with that of hydrogen shows that the former contains twice as much hydrogen per molecule as does free hydrogen, and these facts are best explained by assuming that the molecule of methane contains four atoms of hydrogen, so that the molecule of free hydrogen contains but two. If the assumption is made that the hydrogen molecule contains four atoms, then it must be supposed that the hydrogen of methane can only be removed two atoms at a time, and it would be difficult to understand why this should be the case.

(3) It is known that the number of atoms in a molecule of mercury vapour is almost certainly half the number in a molecule of free hydrogen, as such a conclusion is the only one which is at the same time in harmony with the Law of Dulong and Petit, and with Avogadro's Hypothesis. The ratio of specific heats at constant pressure and constant volume for mercury vapour agrees with the value (1·66) obtained theoretically on the assumption that the molecules themselves do not absorb energy; but in the cases of gases, the molecules of which are known to contain more than one molecule, the ratio of the specific heats is less than 1·66. The abnormality in the latter instance is generally assigned to the complex nature of the molecules of these gases, and if this highly probable assumption be correct, then the mercury molecule must be monatomic, and the hydrogen molecule, therefore, must be diatomic.

ORGANO-METALLIC COMPOUNDS.—Write an account of the recent work of Grignard on the organo-metallic compounds, and discuss their value as synthetical reagents.—*B. E. Honours II.*, 1903.

In 1899, Barbier (Comptes Rendues, 1899, *128*, 110–111) showed that methylheptenone could be converted into dimethylheptenol by the aid of methyl iodide and magnesium turnings if ether were used as a solvent; and in the following year Grignard (*ibid.*, 1900, *130*, 1322–1324) announced that although magnesium acts on methyl iodide extremely slowly, in presence of ether a rapid action occurs, the metal dissolving with the formation of a clear, nearly colourless liquid. This liquid behaves as if it contains magnesium methyl iodide, for, on addition to it of an aldehyde or a ketone, a compound is obtained which, on treatment with dilute acids, affords a secondary or tertiary alcohol, *e.g.*—

$$CH_3\cdot Mg\cdot I + C_6H_5\cdot CO\cdot CH_3 = C_6H_5\cdot C(CH_3)_2\cdot O\cdot Mg\cdot I.$$

$$C_6H_5\cdot C(CH_3)_2\cdot O\cdot Mg\,I + HOH = C_6H_5\cdot C(CH_3)_2\cdot OH + MgI\cdot OH.$$

The method was applicable with alkyl iodides and bromide, and the yields obtained were good. Even benzyl chloride could be used, but with less satisfactory results. By the action of the magnesium solutions on unsaturated ketones, the alcohols first formed lost water, affording unsaturated hydrocarbons. Thus mesityl oxide with magnesium, methyl iodide, and ether gave not

$$C(CH_3)_2:CH\cdot C(CH_3)_2\cdot OH,$$

but

$$C(CH_3)_2:CH\cdot C(CH_3):CH_2.$$

Later (*ibid.*, 1901, *132*, 336–338) Grignard found that the magnesium solutions acted on carboxylic esters in such a way that two alkyl groups became attached to the carbon atom of the carboxyl group, the product being a tertiary

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alcohol: thus with magnesium, amylbromide, and methyl acetate,

$$2C_5H_{11}\cdot Mg\cdot Br + CH_3\cdot CO\cdot OCH_3$$

gave $$CH_3\cdot C(C_5H_{11})_2\cdot OH.$$

Endeavours to isolate the magnesium alkyl bromides or iodides from the ethereal solutions led to the discovery that they usually separate in combination with ether, which is lost at 150° in a vacuum; at higher temperatures the compounds decomposed, yielding the corresponding ethylenic hydrocarbons. The formation of these crystalline compounds with ether has been attributed to an exhibition of quadrivalency by the oxygen atom, and it has been shown that magnesium also dissolves in solutions of alkyl iodides in tertiary amines like dimethyl aniline; further, quite recently the discovery has been made that benzene, etc., may be used as the diluent if a few drops of ether or a tertiary base be added to act as a catalytic agent. The properties of the liquids so obtained are very similar to those employed by Grignard.

By the action of Grignard's compounds on esters of ketonic acids, the latter are first attacked at the ketonic carbonyl group. The alcohol so obtained may have water withdrawn from it, when the carboxyl group may then be attacked by the magnesium compound, and in this way terpin has been synthesised from ethyl γ-ketohexamethylene carboxylate.

Nitriles react with the magnesium alkyl compounds in such a manner that the alkyl group becomes attached to the carbon of the cyano group; the products obtained are ketones and ammonia. Thus ethyl magnesium iodide and benzonitrile yield ethyl phenyl ketone $C_6H_5\cdot CO\cdot C_2H_5$.

Finally, it should be mentioned that the halogen compounds of the aromatic hydrocarbons, such as bromobenzene, react quite readily with magnesium when in ethereal solution, and the products have properties very similar to those of the magnesium alkyl iodides. This is a point of considerable importance, as these substances do not yield organo-metallic compounds with zinc, so that the discovery has opened an entirely new field of research.

ACID.—State and illustrate the meaning which has from time to time been given to the expressions "weak base" and "strong acid."—*Board of Education, Chemistry, Stage III.*, 1904.

The first ideas formed by chemists on the relative affinities of acids were based on the fact that some acids were apparently capable of driving others out of combination with bases, and were therefore classed as the "stronger" acids. Later it was found that, by varying the experimental conditions, the apparent relative strengths of two acids, as determined on this principle, might quantitatively be reversed; thus, although sulphuric acid drives out boric acid from aqueous solutions of borates at ordinary temperatures, yet at a high temperature boric acid is capable of converting sulphates into borates. In consequence, suggestions were made that tables of relative affinities at different temperatures should be constructed.

Bergmann held the view that an acid has the strongest affinity for that base of which it neutralises the largest quantity by weight.

Berthollet was the first to recognise the importance of mass action effects and the manner in which they might influence the relative affinities of acids and bases as measured by the old methods; he pointed out that the physical state of the agents and products must be taken into account in all instances.

Thomsen regarded the heat development during the neutralisation of an acid by a base as a measure of their chemical affinities, an assumption which the later developments of physical chemistry have shown to be unsound.

The modern conception of mass action, the experiments of Guldberg and Waage, of Ostwald and of Arrhenius, have resulted in the establishment of the following principle.

Acids, as a class, are distinguished from other classes of compounds by certain properties of their solutions, and, in particular, of their aqueous solutions. Such properties are, for example, their capacity for promoting the hydrolysis of esters, of inverting cane sugar, and of forming salts with bases. Equivalent quantities of all acids dissolved in an infinite amount of water would be equally effective, and manifest their maximum acidic effect. In concentrated solution they differ very considerably. At a particular temperature and concentration each acid has a characteristic function $=\frac{\text{equivalent acidity at experimental dilution}}{\text{equivalent acidity at infinite dilution}}$. The denominator of this fraction, as has just been indicated, is probably the same for all acids. The strong acids are those in which these numerators are the largest when solutions of equivalent concentrations are compared. For monobasic acids, the relative affinities may be regarded as inversely proportional to the volumes of the aqueous solutions, containing equivalent quantities of the acids, in which the acids exhibit one-half their theoretically possible acidic power.

In the case of bases which act as such in virtue of hydroxyl groups which they contain, similar considerations apply, but if ammonia and similar compounds which form salts by combining with acids are included as bases, complications arise which it would occupy too much space to discuss here.

ANALYST.—State exactly how you would completely analyse quantitatively a nickel steel. What are the best works on this subject and on quantitative analysis generally?

For general quantitative analysis, the book you already possess by Clowes and Coleman is excellent, but a more exhaustive one is Fresenius' Quantitative Analysis (Churchill: 2 vols., 15*s.* and 20*s.*), the second part of which treats of the special analysis of commercial products. For iron and steel analysis only, either

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Arnold's Steel-Works Analysis (Whittaker: 10*s.* 6*d.*) or Brearley and Ibbotson's Analysis of Steel-Works' Materials (Longman's: 14*s.*) would answer all requirements.

A complete analysis of a nickel steel would involve the determination of carbon, silicon, sulphur, phosphorus, manganese, and perhaps copper and arsenic, besides the special element nickel. Moreover, nickel steels frequently contain chromium, so that a description of the analytical procedure for each of these elements would occupy too much space, and "Analyst" is referred to the works mentioned above. The presence of nickel does not interfere with the determination of any of the other elements by the methods usually practised and described, except that a determination of carbon by the Eggertz colour test is out of the question. The nickel itself is determined with the utmost accuracy by the following process.

Weigh off two grams of the steel drillings into a flask of the Erlenmeyer pattern, having a capacity of slightly more than a litre (30 oz.), and add 20 cc. of strong hydrochloric acid. When, after heating, the drillings have dissolved, add about 5 cc. of strong nitric acid to oxidise the iron, and dilute with cold or lukewarm water to about 400 cc. Add now with constant shaking a strong solution of ammonium carbonate; each addition results in the formation of a precipitate, which dissolves on shaking to a solution growing darker and darker in colour, so as to appear ultimately almost black when viewed in bulk. Towards the end of the neutralisation, the flask seems to pull on the hand during the shaking, and the addition of the carbonate must then be made in very small quantities at a time. When a brown precipitate (not too copious) forms, and no longer dissolves on shaking, take it into solution again by adding 10 to 20 cc. of acetic acid of B.P. strength: after diluting with warm water up to about 950 cc., heat the dark-coloured solution up to boiling, inserting a thermometer in the liquid. If more than 20 cc. of acetic acid are required to completely dissolve the precipitate, it is not advisable to carry the assay forward; a fresh one should be started, and more care exercised in the ammonium carbonate neutralisation.

The solution which is being heated will become turbid, and a considerable quantity of ferric hydrate will separate before boiling point is reached. If there are no signs of a turbidity below 70° C., the separation of the iron and nickel is always very complete. When this temperature has been passed, add *not more than* 2 *cc.* of ammonium acetate solution made by neutralising 0·880 ammonium hydrate with B.P. acetic acid (33 per cent.). After boiling for two or three minutes, the contents of the flask are transferred to a litre flask and made up to the mark with hot water, after which 500 cc. are filtered through a dry paper into a graduated flask. This filtrate, representing one gram of the steel, contains the nickel, and should be free from iron. No correction is necessary for the volume of the precipitated ferric compound; but an allowance for contraction by cooling during filtration is made by heating the filtrate up to the same temperature at which filtration was commenced, removing superfluous liquid by means of the thermometer.

The 500 cc. of filtrate are emptied into a large flask and cooled rapidly; ammonium hydrate is then added to produce faint alkalinity, and then a small crystal or two of potassium iodide. From a burette charged with a solution of silver nitrate containing exactly 1·70 grams of the crystals in 1 litre of water, about 5 cc. of solution are run into the flask, thus forming a yellowish turbidity of silver iodide. A second burette contains a slightly ammoniacal solution of potassium cyanide (about 1·5 grams per litre); this solution is delivered about 2 cc. at a time, the flask being shaken after each addition, until the turbidity is just cleared. The exact end point is capable of the nicest adjustment, as, in the event of its being overshot, more silver solution can be run in to reproduce the turbidity. The total amount of cyanide used represents the nickel together with the silver added. It now only remains to ascertain the strength of the cyanide solution in terms of the standard silver nitrate. About 20 cc. more of the silver solution are run into the same flask in which the titration has just been made, and the turbidity thus produced is again cleared by means of the cyanide; the readings are then taken. Each cc. of the silver solution represents 0·000293 grams of nickel.

The end point of the reaction is rendered more distinct by the addition of a gram or two of ammonium sulphate.

LIQUOR AND ASH FROM SULPHATE WOOD PULP.—Can you give me an easy and quick method of analysing the recovered ash, and also the causticised lye before boiling the wood with it, in the sulphate process, with equations and examples of working?

For the rapid approximate estimation of sodium carbonate, sulphide and sulphate of ash recovered in the "sulphate" process, we recommend the following:—

The recovered ash can be rapidly tested as follows. Take sample, grind to fine powder, weigh out 50 grams: dissolve in water, make up to 500 c.c. with distilled water. Take 10 c.c.'s of this in about 300 c.c.'s recently boiled cold distilled water, titrate with normal acid in the presence of phenol phthalein until colour is just discharged. As the above indicator receives its neutral point on the formation of bicarbonate, the reading of the acid consumed multiplied by 2 and by 0·0053 gives the amount of sodium carbonate present.

If the titration is slowly and carefully done in dilute solution there should be no likelihood of decomposing the sulphide. The foregoing is recommended as very rapid and approximately accurate.

$$Na_2CO_3 + HCl = NaHCO_3 + NaCl.$$

For the more accurate determination of

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sodium carbonate in presence of sulphide, barium chloride is added in excess. The barium carbonate so formed is washed on filter paper, and titrated with standard hydrochloric acid.

$$Na_2CO_3 + BaCl_2 = 2\,NaCl + BaCO_3$$

$$BaCO_3 + 2\,HCl = BaCl_2 + CO_2 + H_2O.$$

For the estimation of sulphide the following simple process, recommended by Sutton, can be used with advantage.

Pour 10 c.c. of ash liquor into a flask, acidulate with acetic acid, dilute to about 200 c.c., and titrate with decinormal iodine and starch. Each 1 c.c. = 0·0039 Na_2S.

For the estimation of sulphate the following method can be adopted.

The solution is neutralised, normal barium chloride is added in excess, then normal sodic carbonate in excess of the barium chloride, and the volume of both solutions noted; the liquid is then made up to 200 c.c.'s in a flask, and an aliquot portion filtered off and titrated with normal acid. The difference between the barium chloride and the sodium carbonate gives the sulphates. The changes take place in accordance with the undermentioned equations.

$$Na_2SO_4 + BaCl_2 + BaCl_2 = BaSO_4 + 2\,NaCl + BaCl_2$$

$$BaCl_2 + Na_2CO_3 + Na_2CO_3 = BaCO_3 + 2\,NaCl + Na_2CO_3$$

$$Na_2CO_3 + 2\,HCl = 2\,NaCl + CO_2 + H_2O$$

Recovered Ash.—We assume that the causticised lye contains the following ingredients:—Sodium carbonate, caustic soda, sodium sulphide, sodium sulphate. The sulphide and sulphate can be determined as in the case of the recovered ash.

For the determination of the carbonate and caustic, proceed as follows when sulphide is present in small quantities or entirely absent.

Measure 10 c.c. of the clear causticised liquor into a flask or porcelain dish containing 200 to 300 c.c. of recently boiled and cooled distilled water. Add carefully and slowly decinormal hydrochloric acid in the presence of phenol phthalein until the colour is discharged; then add methyl orange and titrate until the neutral tint appears. Double the difference between the phenol phthalein and methyl orange reading represents the carbonate: the methyl orange reading represents the carbonate and caustic. Therefore in order to arrive at the amount of caustic the figure for the carbonate is deducted from the total reading of the methyl orange titration.

$$NaOH + Na_2CO_3 + 2\,HCl = 2\,NaCl + NaHCO_3 + H_2O$$ neutral to phenol phthalein.

$$NaHCO_3 + HCl = NaCl + H_2CO_3$$ neutral to methyl orange.

(1) Total alkali existing as carbonate, hydrate, and sulphide, is found by titrating 10 c.c. = 1 gr. of ash with standard acid and methyl orange in the cold.

$$Na_2CO_3 + 2\,HCl = 2\,NaCl + H_2O + CO_2$$

$$NaOH + HCl = NaCl + H_2O$$

$$Na_2S + 2\,HCl = 2\,NaCl + H_2S.$$

(2) Caustic soda: 20 c.c. of the liquid is put into a 100 c.c. flask with 10 c.c. of solution of baric chloride of 10 per cent. strength, filled up with hot water, well shaken, and corked after settling a few minutes. The clarified liquid is filtered, and 50 c.c. = 1 gr. ash, titrated with standard acid and methyl orange; or it may be titrated without filtration if standard oxalic acid and phenolphthalein are used, this acid having no effect on the baric carbonate. Each c.c. normal acid = 0·031 Na_2O. This includes sulphides.

$$Na_2CO_3 + NaOH + BaCl_2 = BaCO_3 + 2\,NaCl + NaOH.$$

$$NaOH + HCl = NaCl + H_2O.$$

(3) Sodic sulphide.—Put 10 c.c. of liquor into a flask, acidulate with acetic acid, dilute to about 200 c.c., and titrate with $\frac{N}{10}$ iodine and starch. Each c.c. = 0·0039 Na_2S, or 0·0031 Na_2O.

For calculation of results.—From total soda as determined in (1) deduct soda as sulphide and caustic as determined in (2), which gives the sodium carbonate. The caustic is determined by deducting sulphide (3) from caustic and carbonate (2), and (3) gives the sulphide.

GEOMETRICAL OPTICS.—A, B are two points, and D E is the section of a convex spherical mirror (centre C), by the plane through A, B, and C. Find the path of a ray of light from A which, on being reflected by the mirror, will pass through B. A locus may be used if necessary.

Join A C. Starting from the point where the line A C cuts D E, step out the curve D E in

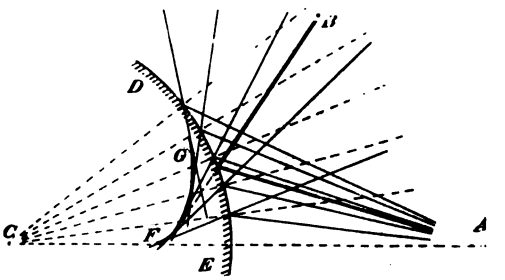

FIG. 1.—GEOMETRICAL OPTICS.

equal parts, and through the points thus obtained, draw straight lines from C. Each of these radial straight lines will be normal to D E at the point of intersection. If we join A to any one of the points just found, we obtain the path of an incident ray; we can at once find the corresponding reflected ray by drawing it from the point of incidence, so that the incident

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and reflected rays lie on opposite sides of the normal and are equally inclined to this. Find the reflected rays at the various points on D E cut by the radii: produce the reflected rays backwards through the mirror, when it will be found that they envelop a curve F G, which is termed the *caustic* curve. Since each reflected ray touches this curve, we can find the reflected ray passing through B by drawing a straight line from B to touch the curve F G. Join A to the point where this reflected ray cuts D E, and this will give us the corresponding incident ray.

GRAVITATION.—At what distance from the centre of the earth is the force of gravitation at a maximum? Draw a curve, having distances along a radius from the centre of the earth as abscissæ, and force of gravitation as ordinates.

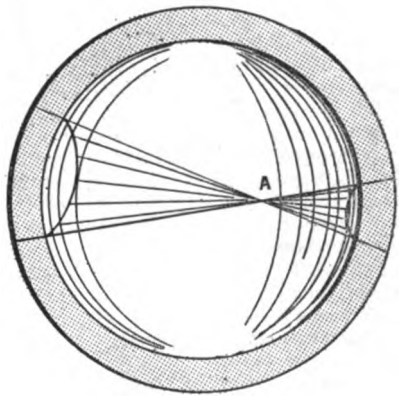

FIG. 1.—(GRAVITATION.)

The gravitative pull of one particle on another follows a law similar to that regulating the pull between two charged particles or two magnet poles: in other words, the pull between two particles varies directly as the product of their masses, and inversely as the square of the distance separating them. The pull of a large spherical mass on unit mass placed outside it

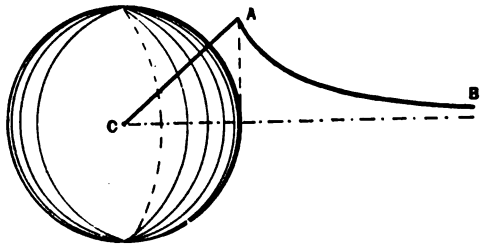

FIG. 2.—(GRAVITATION.)

varies inversely as the square of the distance from the centre of the sphere to the unit mass. Hence the force of gravitation at any point outside the earth varies inversely as the square of the distance of the point from the centre of the earth, and is thus represented by the curve AB, Fig. 2.

The attraction of a hollow spherical shell on unit mass placed anywhere within it is equal to zero. This can be proved as follows:— Let A, Fig. 1, be a point within the shell. From A draw numerous lines produced to cut the shell on both sides, thus enclosing a double cone. The base of either cone is directly proportional to the square of the altitude of the cone, and therefore the masses of matter cut off from the shell by the two cones are proportional to the squares of the respective altitudes of the cones. On the other hand, the attraction at A due to *unit mass* of the matter cut off by either cone is inversely proportional to the square of the altitude; consequently the resultant pulls on a unit mass at A, due to the matter cut off by the bases of the two cones, just neutralise each other. Since the whole of the shell may be divided up by means of cones similar to those shown in Fig. 1, it follows that the resultant pull of one half of the shell will just neutralise the resultant pull of the other half of the shell on unit mass at A.

Thus, in descending into the earth, the force of gravitation due to the shell through which we descend is equal to zero, and the resultant pull of gravitation is that due to a sphere, of which the radius is the distance of the point of observation from the centre of the earth. The mass of matter contained in this sphere varies as the cube of the radius, and therefore the pull due to this sphere varies as the cube of the radius divided by the square of the radius, *i.e.*, the pull is proportional to the radius. Thus, at points within the earth, the pull of gravitation may be represented by the line CA, Fig. 2, and we see that the greatest pull due to gravitation occurs at the surface of the earth.

PRACTICAL MATHEMATICS.—At corresponding high speeds of modern ships of the same class, if V is the speed in knots, D the displacement in tons, P the indicated H.P., T the time spent in a particular passage, C the coal consumed,

$$V \propto D^{\frac{1}{6}},\ P \propto D^{\frac{2}{3}}V^3,\ C \propto PT.$$

Show how P, T, and C depend on D alone.

A cross-Atlantic steamer of 10,000 tons at 20 knots crosses in 6 days, its power being 20,000, using 2,520 tons of coal. What must be the displacement, the speed, the power, and the coal for a vessel which makes the passage in 5 days?—*Board of Education, Practical Mathematics, Stage III.*, 1904.

To show that P, T, and C can be expressed merely in terms of D:—

$$P \propto D^{\frac{2}{3}}(D^{\frac{1}{6}})^3 \text{ or } D^{\frac{7}{3}}$$

$$C \propto PT \text{ or } D^{\frac{5}{3}}T.$$

Also, for a given passage, $V \propto \frac{1}{T}$;

$\therefore$ $\frac{1}{T} \propto D^{\frac{1}{6}}$, and $T \propto D^{-\frac{1}{6}}$.

$\therefore$ $C \propto D^{\frac{5}{3}} \times D^{-\frac{1}{6}}$ or D.

Thus $P \propto D^{\frac{7}{3}}$,

$C \propto D$,

$T \propto D^{-\frac{1}{6}}$.

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SECOND PART OF QUESTION. — *Displacement.*- As proved above, $D \propto T^{-6}$.

Hence $\frac{D}{10{,}000} = \left(\frac{6}{5}\right)^6 = 2{\cdot}986.$

$D = 29{,}860.$

Speed.—$V \propto \frac{1}{T}$, $\therefore \frac{V}{20} = \frac{6}{5}$.

$V = 24$ knots.

Power.—$P \propto D^{\frac{1}{2}}V^3 = V^4 . V^3 = V^7 = \left(\frac{1}{T}\right)^7$;

$\therefore \frac{P}{20{,}000} = \left(\frac{6}{5}\right)^7 = 3{\cdot}585$

$P = 71{,}700.$

Coal.—$C \propto D \propto V^6 \propto \left(\frac{1}{T}\right)^6$;

$\therefore \frac{C}{2520} = \left(\frac{6}{5}\right)^6 = 2{\cdot}986$

$C = 7{,}509.$

TOOTHED WHEEL.—State the principles which govern the design of wheel teeth. Sketch a form of tooth suitable for the spur-wheels connecting a pair of crushing rolls, each 18 inches diameter, when the distance between them is liable to be varied from 0–$\frac{3}{4}$ inch. The pitch to be as nearly 4 inches as possible when the rolls touch.

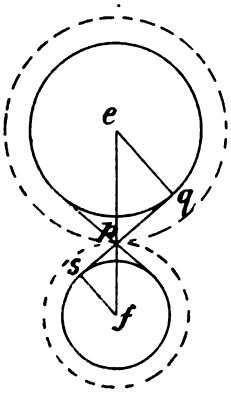

FIG. 1.

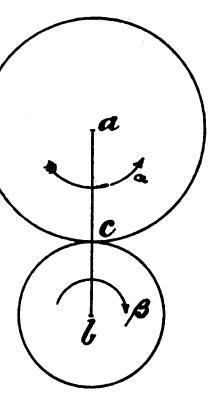

FIG. 2.

(TOOTHED WHEEL.)

A pair of gear wheels is simply a substitute for a crossed belt-drive, with the centres of the pulleys near together. Fig. 1 indicates the arrangement when the surfaces of the pulleys do not touch, and Fig. 2 when they touch.

If there is to be no slipping of the belt, then *the belt and the surfaces of the pulleys must move at the same speed*, and in consequence the circles in Fig. 2 will appear to roll upon one another, contact between them always taking place at C on the line of centres. Let a and β be their angular velocities, then $a \times ca = \beta \times bc$ = common velocity of circumferences of circles. These are called pitch circles, and their point of mutual contact (c) is called the pitch point. Hence, *the radii of the pitch circles are inversely as their angular velocities.*

The same holds for Fig. 1, for if eq and sf are radii drawn perpendicular to the common tangent sq, the angles at s and q are right angles, and the angle spf is equal to the opposite angle epq; thus the triangles are similar, and

$$\frac{\beta}{a} = \frac{eq}{sf} = \frac{ep}{fp};$$

hence if two circles (shown dotted) be drawn from e and f as centres, and passing through the point p, in which the tangent cuts the line of centres, these circles are the pitch circles, and behave in every way as those in Fig. 2.

If a tooth on one wheel gears with a tooth on the other, then *the curve of one must be the envelope of the other during contact.* For, suppose one wheel to be fixed (say the lower one), and let the other move round it, the distance between their centres being constant. In Fig. 3 the different positions of a tooth on the upper wheel are shown; the lower tooth contour touches all these curves, and is therefore their envelope during contact.

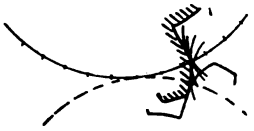

FIG. 3.—(TOOTHED WHEEL.)

In Fig. 4 the pitch circles are shown, the lower one being still fixed. The teeth are in contact at i; as at this point one tooth cannot penetrate the other, *their speeds along the common normal to their surfaces at the point of contact must be equal.* But the lower tooth was assumed for the time being to be fixed; hence the speed of both along the common normal must be zero; that is, the upper tooth can have no velocity along the normal, but only perpendicular to it, and hence it must turn about some point in the common normal; or in other words, the common normal must pass through the point about which the upper circle is instantaneously turning, and which is the pitch point p. *Hence the common normal at the point of contact of two teeth must always pass through the pitch point.*

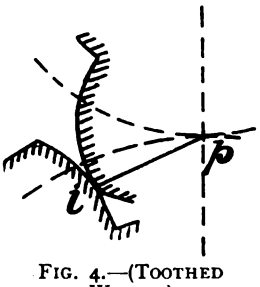

FIG. 4.—(TOOTHED WHEEL.)

The above conditions may be satisfied by making the tooth contours parts of an epicycloid and a hypocycloid. Thus in Fig. 5 let the pitch circles touch at p, and a third circle, with the centre indicated, touch the pitch circles at p, so that the

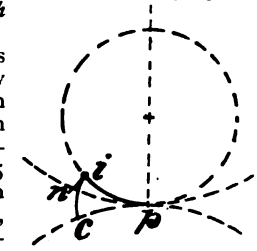

FIG. 5.—(TOOTHED WHEEL.)

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three circumferences roll together without slipping. A point i on the small rolling circle will move along the arc $p\,i$, and during that motion will trace on the lower wheel the epicycloid $c\,i$, because the rolling circle rolls on the lower pitch circle. Similarly the same point i will trace the hypocycloid $n\,i$ on the upper wheel for the same reason. Also the curve $c\,i$ must be in contact with the curve $n\,i$ at the point i wherever it may be, because i, the generating point, is simultaneously generating both curves. Note that in this case the pitch circles are continually in contact at the pitch point, as in Fig. 1, and hence the angular velocities of the wheels must be inversely as their radii. Also that the generating point is continually turning round the pitch point relative to either wheel; and therefore the common normal must pass through the pitch point. The path or locus of the point of contact of two teeth in gear must be the path of the generating point, which is an arc of the rolling circle.

Another arrangement which satisfies the main conditions above is that in which the path of contact, and consequently the path of the generating point, is a straight line passing through the pitch point. The generating point in this case traces out the involute of a circle on each wheel. These circles are called *base circles* and are shown by full lines in Fig. 1. That the contours must be involutes can easily be seen if one wheel is assumed to rotate round the other, which may be fixed. Then the tracing point is on a band which gradually unwraps from a base circle, which is a definition of an involute.

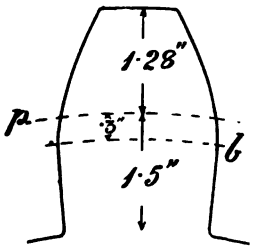

FIG. 6.—(TOOTHED WHEEL.)

One of the chief features of involute teeth is that they admit of the wheel centres being moved apart without altering the velocity ratio; for the same contours will be described by the generating point whatever be the distance apart of the centres, the actual curves depending only on the base circles; hence, where the distance apart of wheels is variable, such as suggested in the question, involute teeth should be used.

It is customary to arrange the inclination of the locus of contact with the tangent at the pitch point about $15\frac{1}{2}^\circ$. This locus touches the base circles, and hence the base circles can be drawn to scale; one is shown in Fig. 6 at b. The thickness of a tooth and the corresponding width of space at the base circle is usually made equal to half the pitch, and in this case will be 2 inches. The usual height above the pitch circle (p, Fig. 6) is 0·32 of the pitch, or 1·28 inch. Depth of tooth below pitch circle = 0·37 of the pitch, or 1·48 inches, say 1·5 inches.

The involute can now be drawn together with the outline of the tooth, as shown in Fig. 6; the flanks below the base circles being radial. On separating the centres of the wheels by $\frac{1}{4}$ inch, it will be found that two teeth will be in contact for rather more than the pitch, and hence the wheels will gear satisfactorily when separated as suggested. It may be advisable to lengthen the teeth about $\frac{1}{8}$ inch to procure a slightly longer arc of contact. The reader should consult Professor Unwin's "Elements of Machine Design," for a thorough investigation of this subject.

HYDRAULICS.—Eight thousand gallons an hour have to be discharged through each of six nozzles, and the jet has to reach a height of 80 ft. If the water supply is 1½ miles away, at what elevation above the nozzles would you place the required reservoir, and what would you make the diameter of the single supply main? Give the dimensions of the reservoir you would provide to keep a constant supply for six hours.

$$48{,}000 \text{ gals. per hour} = \frac{48{,}000}{3{,}600} \text{ gals. per sec.}$$

$$= \frac{48{,}000}{3{,}600} \times \frac{1}{6{\cdot}25} = 2{\cdot}13 \text{ cub. ft. per sec.}$$

The velocity of the water through the main must not be great, or the loss of head due to friction will be great; at the same time, if the velocity is very small, the diameter of the pipes, and consequently their cost, will be excessive.

It is customary to allow the velocity in long mains to be 3 ft. per sec. If d = diameter of pipe in feet, then the volume of water discharged per sec. must be $3 \times \frac{\pi}{4} d^2$ cub. ft.;

hence $$2{\cdot}13 = 3 \times \frac{\pi}{4} \times d^2,$$

or $$d = 0{\cdot}95 \text{ ft.}$$

$$= 11\tfrac{1}{2} \text{ in.}$$

The loss of head due to friction

$$= {\cdot}03 \times \frac{l}{d} \times \frac{v^2}{2g},$$

l being the length of the pipe. Substituting for l, d and v, we obtain 35·3 ft. as the loss of head due to friction, and this is the extra height above the 80 ft. of jet at which the reservoir must be placed so that the required velocity may be given to the water to reach the height of 80 ft. Total height above jet = 35 + 80 = 115. But valves, bends, etc., must be introduced to control the supply, and these cause extra resistance of the same nature as friction. Without further data this cannot be calculated, but it would be safe to allow another 5 ft. of head to cover these losses, making the total elevation of the base of the reservoir above the jets 120 ft.

The necessary volume of the reservoir must be the number of cubic feet occupied by 6 times 48,000 gallons, or

$$\frac{6 \times 48{,}000}{6{\cdot}25} = 46{,}000 \text{ cub. ft.}$$

If the reservoir were 10 ft. deep, then the mean horizontal surface of the water must be

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4,600 sq. ft., or, say, 100 ft. × 46 ft.; or if 5 ft. deep, the area must be 100 ft. × 92 ft.

HAND CRANE.—From the dimensions given in the accompanying diagram, find the greatest load W that can be suspended from the end A? The material is mild steel. The frame is supported by angle brackets, which are assumed to be strong enough for the work required.

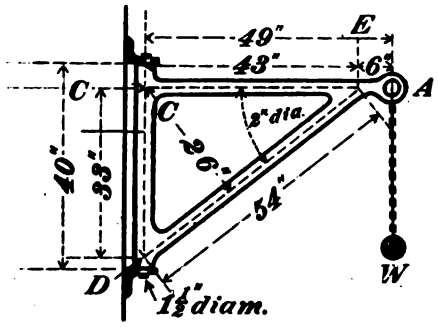

FIG. 1.—(HAND CRANE.)

From an inspection of the sketch it would appear that the stress will be greatest at the point E, or in the strut A D. Let us first consider the strength at the point E.

Let Z = the section modulus in inches³.

Let f = the maximum safe stress on the extreme fibres of a beam or cantilever.

The bending moment at E = W tons × 6 ins.

For a round iron bar of D inches diameter $Z = \frac{\pi}{32} D^3$, or approximately $\frac{1}{10} D^3$.

When D = 2 ins., $Z = \frac{8}{10}$ ins³.

For mild steel $f = 7$ tons per sq. inch.

Since bending moment = moment of resistance,

$$6W = Zf;$$

$$\therefore 6W = \frac{8 \times 7}{10};$$

$$\therefore \quad W = \frac{56}{60} = \frac{14}{15} \text{ tons.}$$

We see, therefore, that a load of rather less than a ton will bring the stress at E up to 7 tons per square inch.

Let us now ascertain what load will be required to stress the strut A D up to its working limit.

Let l = the clear length of the strut = 52 ins. approximately.

d = its diameter in inches = 2 ins.

$m = l/d = 26$.

a = a constant depending on material.

p = a constant depending on form of pillar.

f = the crippling load on a strut or pillar in tons per sq. inch.

For struts with fixed ends, Gordon's formula is $f = \frac{a}{1 + bm^2}$ or $\frac{a}{1 + b\left(\frac{l}{d}\right)^2}$

For mild steel $a = 20$.

For solid round bars $b = \frac{1}{2500}$,

$$\therefore f = \frac{20}{1 + \frac{m^2}{2500}}$$

$$m^2 = 676 \therefore f = \frac{20}{1 + \frac{676}{2500}}$$

$$= \frac{20 \times 2500}{3176} = 15{\cdot}8 \text{ tons per sq. inch.}$$

Using a factor of safety of 6 to allow for any initial lateral distortion of the strut due to previous rough usage, the working stress will be

$$15{\cdot}8/6 = 2{\cdot}63 \text{ tons per sq. inch.}$$

The area of a 2-inch diameter bar = 3·14 sq. ins.

The total safe load on the strut

= 2·63 tons per sq. inch × 3·14 sq. ins.

= 8·3 tons.

This is the maximum safe load on A D. We now require to find what load on W will produce 8·3 tons on A D.

Take moments about the point C, *i.e.*, the intersection of the vertical and horizontal bars.

For equilibrium,

8·3 tons × 26 ins. = W tons × 49 ins.

$$\therefore \frac{8{\cdot}3 \times 26}{49} = W = 4{\cdot}4 \text{ tons.}$$

We see then that the frame is more likely to fail at E than between A and D.

Let us now try the resistance to shearing of the two pivots. These pivots are 1½ inch diameter, and at 5 tons per square inch the resistance of each to shearing = 8·8 tons nearly.

The clockwise couple

= W tons × 49 ins.

The anti-clockwise, or resisting couple,

= 8·8 tons × 40 ins.

For equilibrium, W × 49 = 8·8 × 40,

$$\therefore W = \frac{8{\cdot}8 \times 40}{49}$$

$$= 7{\cdot}2 \text{ tons.}$$

We see then that E is still the weakest point, and will therefore govern the maximum load which can be hung from A.

It should be borne in mind that if a weight Z be lifted by means of a single simple pulley block with a vertical and downward pull, the total downward pressure will be 2 Z; but as the question simply gives a single pendant load, we have taken no account of how W is made up.

TRANSFORMER.—If the primary terminals of a transformer are connected to an alternating current supply, explain what becomes of the electric energy supplied to the transformer. (a) If the secondary circuit is open; (b) If the secondary circuit is closed through a resistance, such as a number of lamps in parallel. — *M. 4. Honours, R.U.I.*, 1902.

In giving a brief reply to this question the information given in J. J. Thomson's "Elements

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of Electricity and Magnetism *re* Transformers" will be assumed to be known, and the following notes refer to the practical working of a transformer rather than to the mathematical theory of the transformer. When the secondary is on open circuit, the action of a transformer is the same as if the secondary circuit were removed: the primary impressed pressure has simply to overcome the resistance of the primary circuit and the self-induction set up, and to supply the current required to magnetise the core. The work done is therefore equal to the energy spent, from instant to instant, in heating the primary circuit and the core of the transformer. The former is equal to $(C_1^2 R_1)$ watts, where C_1 is the primary current, and R_1 is the resistance of the primary windings, and the latter—known as the iron losses—is made up of the hysteresis and eddy-current losses. If W_i denote the iron losses, then

$$W_i = \text{volume} \times \left\{ \frac{\eta f B_{max.}^{1.6}}{10^7} + \frac{t^2 f^2 B_{max.}^2}{10^{16}} \right\} \text{ watts},$$

the volume of the iron being given in cubic centimeters; η is the hysteresis co-efficient ($= 0{\cdot}0024$), f is the frequency, B is the flux-density, and t is the thickness of the laminations in mils. The power supplied is therefore

$$P_1 = C_1^2 R_1 + V \left\{ \frac{\eta f B_{max.}^{1.6}}{10^7} + \frac{t^2 f^2 B_{max.}^2}{10^{16}} \right\}$$

if V is the volume of the iron traversed by the magnetic flux in cubic centimeters.

When the secondary circuit is closed, the effect is the same as if the apparent self-induction of the primary circuit were diminished, whilst its resistance is increased. This enables a larger current to traverse the primary circuit: the energy absorbed is that required to make up the losses in the primary and secondary circuits, and the iron losses, together with the power absorbed by the lamps inserted in the secondary circuit. If P denotes the useful power absorbed by the lamps, and C_2 is the secondary current, while R_2 is the resistance of the secondary windings, then the power supplied to the primary circuit is

$$\begin{aligned} P_1 &= \{C_1^2 R_1 + C_2^2 R_2\} \\ &\quad + V \left\{ \frac{\eta f B_{max.}^{1.6}}{10^7} + \frac{t^2 f^2 B_{max.}^2}{10^{16}} \right\} + P \\ &= \text{copper losses} + \text{iron losses} \\ &\quad + \left\{ \begin{matrix} \text{power absorbed} \\ \text{by the lamps.} \end{matrix} \right\} \end{aligned}$$

It may be mentioned that the iron losses are constant, and therefore represent a permanent amount of dissipation of energy so long as the transformer is connected to the supply circuit, whatever may be the magnitude of the secondary current.

CALCULUS.—Prove (geometrically) that the area of the greatest ellipse inscribed in a given triangle is

$$\frac{\pi}{\sqrt{27}}$$

of the area of the triangle. Find the area of the least ellipse circumscribing the same triangle.— (*Williamson's Differential Calculus*, page 165.)

Project the given triangle orthogonally into an equilateral triangle, then any ellipse inscribed in the given triangle will be projected into an ellipse (generally speaking) inscribed in the equilateral triangle.

Then

$$\frac{\text{area of ellipse}}{\text{area of triangle}} = \frac{\text{area of projected ellipse}}{\text{area of equilateral triangle.}}$$

The area of the ellipse will therefore be greatest when the area of the projected ellipse is greatest, and this will happen when it is a circle. But the ratio

$$\frac{\text{area of circle}}{\text{area of circumscribed equilateral triangle}} = \frac{\pi}{\sqrt{27}},$$

which is therefore the ratio of maximum ellipse inscribed in a triangle to the triangle.

The second part of question is similarly answered. On projecting the triangle and any circumscribing ellipse into an equilateral triangle and another circumscribing ellipse we see that the projected ellipse will have minimum area when it is a circle.

Hence

$$\begin{aligned} &\frac{\text{area of minimum ellipse}}{\text{area of triangle}} \\ &= \frac{\text{area of circumscribing circle}}{\text{area of equilateral triangle}} \\ &= \frac{4\pi}{\sqrt{27}}. \end{aligned}$$

[For one learning the calculus, it is a mistake to spend much time on such geometrical problems.]

A. J. S.—From the equation

$$\int_{\frac{a^2}{2}}^{a} \sqrt{a^2 - x^2}\, dx + \int_0^{a^2} \sqrt{2x - 1}\, dx = \frac{\pi}{4}$$

Find the value of a.

If a is a real quantity, then the given equation is meaningless, for when $x = 0$

$$\sqrt{2x - 1} = \sqrt{-1};$$

similarly, on performing the second integration we obtain

$$\tfrac{1}{3} \{ (a^2 - 1) - (-1)^{\frac{3}{2}} \}$$

and the only real value of a which makes this quantity real is zero.

RAILWAY CARRIAGE.—The enclosed sketch is a structure of shape and dimensions given. I shall be glad if you will please ascertain the stresses which occur in all the members, when it is loaded in the various ways specified (see Fig. 1).

The drawing you submit apparently represents the under-frame of a railway carriage, but you do not give several of the essential

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particulars; for instance, it is necessary to know whether the buffing and drawgear are independent of each other, and it is also necessary to know the distance between the centres of bogies. In the following reply we shall assume that the buffing and drawgear are independent, and that the bogie centres are 37 feet apart.

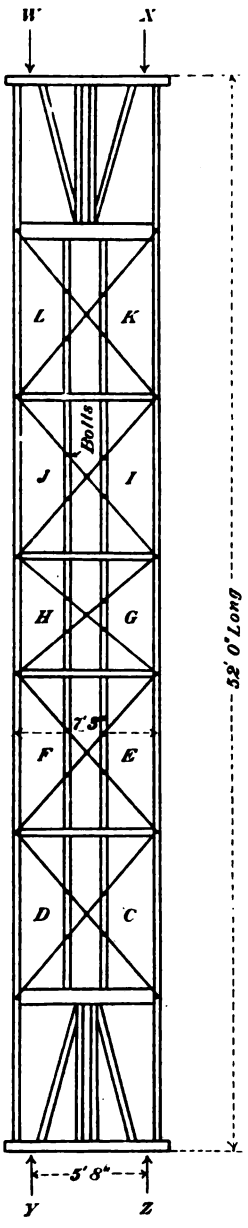

FIG. 1.—(RAILWAY CARRIAGE.)

(*a*) 50 tons at W, 50 tons at Z.
(*b*) { 50 tons at W, 50 tons at X. / 50 tons at Y, 50 tons at Z.
(*c*) { 50 tons at W, 25 tons at Y. / 25 tons at Z.

The stresses are too various, and the frame is too complex for an exact solution, for it is no exaggeration to say that the frame could be fitted together in less time than it would take to make the necessary calculations.

Fortunately, a working solution, which is demonstrably on the safe side, may be obtained quite readily by making the same assumptions as are made by the designers of bridges. These assumptions and methods of attack are as follows:—

1. Neglect the stiffness and rigidity afforded by the joints, and assume all joints to be hinged or pin-connected.

2. Omit the redundant members in each stress diagram.

3. Do not attempt a solution of the complete structure, but split it up into parts; for instance, the stresses on all portions between the bogie centres and the headstocks may be taken out separately.

4. Within reasonable limits, place the actual loads, or place equivalent loads, in such positions that the application of graphical methods is rendered possible. For example, although the end pressures act on the headstocks at a point between the solebar and the end diagonals, we may first make a series of calculations on the assumption that the pressures come directly in a line with the solebars, and then make a series of calculations on the assumption that the pressures are transmitted solely along the end diagonals and the intermediate longitudinals.

5. Remember that members which are redundant for certain conditions of loading may not be redundant for altered conditions. For example, the diagonal flat bars, which are assumed to be idle when the pressures are at W and X, are not idle when the pressures are at W and Z.

Before getting out a diagram of stresses, it is necessary to determine what external forces are acting on the structure to prevent translatory motion, and rotary motion round any point.

For example, when there is a pressure of 50 tons at W and 50 tons at Z, the frame would twist round if it were not for the side pressure of the rails, which is transmitted through the bogie bolster.

Assuming that the end pressures are coincident with the centre lines of the solebars, and assuming that the centres of solebars = 6·83 feet, the lateral pressure will be

$$\frac{50 \text{ tons} \times 6{\cdot}83 \text{ feet}}{37 \text{ feet}} = 9{\cdot}2 \text{ tons.}$$

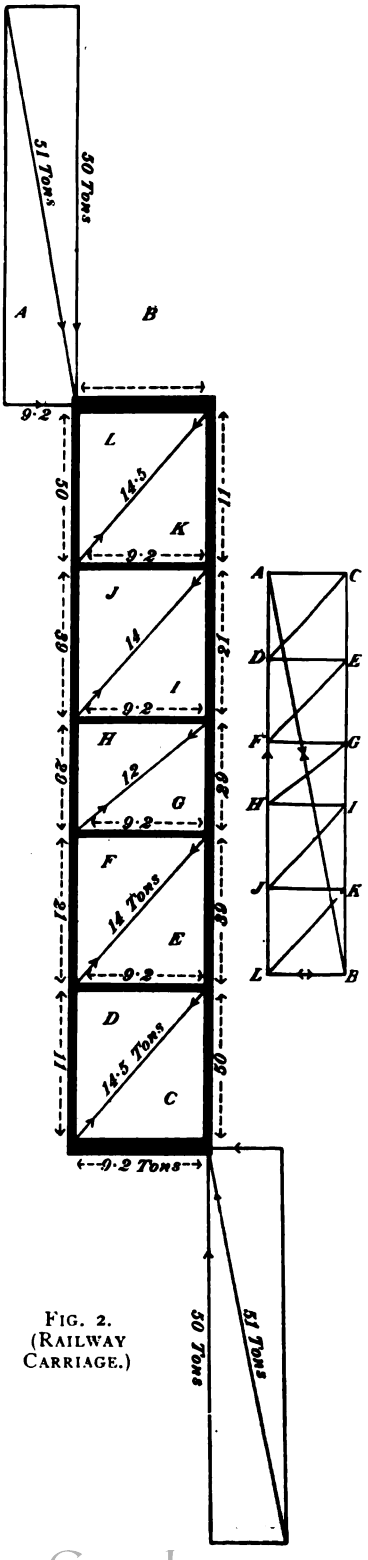

FIG. 2. (RAILWAY CARRIAGE.)

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By combining a force of 50 tons with a normal force of 9·2 tons we get a diagonal resultant of about 51 tons (Fig. 2).

The stress diagram given neglects the stress beyond the bogie bolsters, as these can be seen by inspection.

When the loads are 25 tons at each of the points W,X,Y,Z, the stresses may be assumed as follows :—

Solebars, 12¼ tons each ; intermediate longitudinals, 12½ tons each. Stresses on diagonal flat bars, nil. Stresses on each end oak diagonal, rather more than 12½ tons, say about 13.

With 50 tons at X, 25 tons at Y, and 25 tons at Z the stresses will be the same as for 25 tons at X and 25 tons at Z, with an *additional* 25 tons compression along the solebar WY.

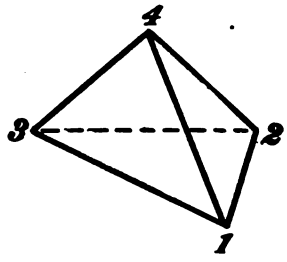
The query does not make any reference to the beam stresses caused by the weight of the carriage body or the pull of the truss rods, but it should not be forgotten that these either sag or hog-back the underframe, and when the compressions from collision or buffer pressures occur, they occur on members which are not mathematically straight.

TETRAHEDRON. — Through the middle point of every edge of a tetrahedron a plane is drawn perpendicular to the opposite edge ; show that the six planes so drawn will meet in a point such that the centroid of the tetrahedron is midway between it and the centre of the circumscribing sphere. — *C. Smith's Solid Geometry, page* 34, *Ex.* 3.

Take the centroid O as the origin of rectangular co-ordinates, and let

$$(x_1 y_1 z_1), (x_2 y_2 z_2) \ . \ . \ . \ (x_4 y_4 z_4)$$

be the co-ordinates of the four vertices 1, 2, 3, 4.



Then, since the centroid is the same as for four equal particles placed at the vertices, we have

$$x_1 + x_2 + x_3 + x_4 = 0 ;$$

and similar equations for the y's and z's.

The equation to any plane through the mid-point of 12 is

$$P\left(x - \frac{x_1 + x_2}{2}\right) + Q\left(y - \frac{y_1 + y_2}{2}\right) + R\left(z - \frac{z_1 + z_2}{2}\right) = 0$$

where P, Q and R are proportional to the direction cosines of the perpendicular to the plane.

This perpendicular must therefore be parallel to 34, whose direction cosines are proportional to $x_3 - x_4$, $y_3 - y_4$, $z_3 - z_4$.

Hence the equation to the plane through the mid-point of 12, perpendicular to 34, is

$$(x_3 - x_4)\left(x - \frac{x_1 + x_2}{2}\right) + (y_3 - y_4)\left(y - \frac{y_1 + y_2}{2}\right) + (z_3 - z_4)\left(z - \frac{z_1 + z_2}{2}\right) = 0.$$

Now $x_1 + x_2 = -(x_3 + x_4)$, etc.

Hence equation to our plane is

$$(x_3 - x_4)\left(x + \frac{x_3 + x_4}{2}\right) + \ . \ . \ . \ = 0,$$

and the equation to the other five planes can be at once written down by changing the suffixes.

Let a_{34} denote

$$-\left(\frac{x_3^2 - x_4^2}{2} + \frac{y_3^2 - y_4^2}{2} + \frac{z_3^2 - z_4^2}{2}\right)$$

(the constant term of the equation to the plane) then for the three planes $\perp^r$ to the edges 34, 41, 12 we can write down their point of intersection in determinants, *viz*,

$$\Delta . x = \begin{vmatrix} a_{34}, & y_3 - y_4, & z_3 - z_4 \\ a_{41}, & y_4 - y_1, & z_4 - z_1 \\ a_{12}, & y_1 - y_2, & z_1 - z_2 \end{vmatrix}$$

Where $\Delta = \begin{vmatrix} x_3 - x_4, & y_3 - y_4, & z_3 - z_4 \\ x_4 - x_1, & y_4 - y_1, & z_4 - z_1 \\ x_1 - x_2, & y_1 - y_2, & z_1 - z_2 \end{vmatrix}$

If we add a_{41} to a_{34} we get

$$-\left(\frac{x_3^2 - x_1^2}{2} + \frac{y_3^2 - y_1^2}{2} + \frac{z_3^2 - z_1^2}{2}\right)$$

which is a_{31}.

Hence, by adding the first two rows in the determinants to a new first row we get the x for the intersection of the planes perpendicular to the edges 31, 41, 12. We see then that we get the same x for the intersection of the six planes taken in groups of three.

By writing down the determinants equal to $\Delta . y$ and $\Delta . z$ we see that the six planes intersect in one point.

If we draw a plane through the mid-point of 34 and perpendicular to it, every point in that plane will be equidistant from 3 and 4. Hence six such planes must intersect in a point which is the centre of the circumsphere of 1 2 3 4.

The direction cosines of the perpendicular to the plane $\perp^r$ to 34 are $x_3 - x_4$, etc., and the equation to the plane through the mid-point is

$$(x_3 - x_4)\left(x - \frac{x_3 + x_4}{2}\right) + \text{etc.} \ . \ . \ . \ = 0.$$

Writing down the equation to two such planes $\perp^r$ to 41 and 12, the constant terms for the three equations are seen to be

$$-a_{34}, \ -a_{41}, \ -a_{12}.$$

Hence the determinants giving the co-ordinates of the centre will only differ in sign from those previously obtained.

If then X, Y, Z, be the co-ordinates of centre of the circumsphere, we have our old

$$x = -X$$
$$y = -Y$$
$$z = -Z ;$$

or the origin is mid-way between the first point determined and the centre of the circumsphere.

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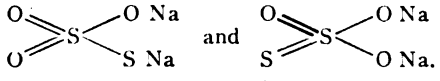
TECHNICS CORRESPONDENCE

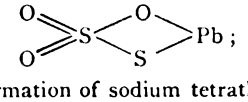
To the Editor of TECHNICS.

SIR,—May I be permitted to call attention to the fact that in some of the "Answers to Queries" which have appeared from time to time, slight errors have occurred Thus in the answer to *Combustion*, Vol. II., page 505, the heat of combustion of 1 gram of carbon is given as 8000 calories ; from this it is evident that the heat of combustion to CO_2 is meant, whereas in the answer it is taken to be CO. If this change is made it will be found that oxide of sodium can be reduced by carbon, whether the oxide be taken as Na_2O or Na_2O_2.

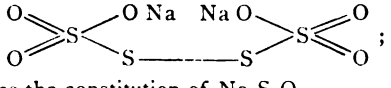
Again, in the various answers to constitutional questions, it is sometimes stated that "there is no evidence to distinguish with certainty between the two formulæ given"; which one would take to mean that there is as much evidence for the one formula as for the other. Thus in the answer to *Theory*, Vol. I., page 505, the two formulæ given for $Na_2S_2O_3$ are



In this case the balance of evidence seems to me to be in favour of the first formula. It is only by means of this formula that one can explain :—(1) The ready formation of PbS by heating up PbS_2O_3 in the presence of water. The S is combined with the Pb in PbS, and this is presumably also the case in PbS_2O_3, which will therefore have the constitution

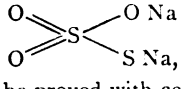


(2) The formation of sodium tetrathionate from $Na_2S_2O_3$ and Iodine. It is the S which permits of the formation of such complexes and the constitution of the tetrathionate is in all probability



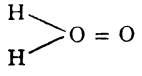
hence the constitution of $Na_2S_2O_3$.

In face of evidence of this kind it seems to me that the above quoted statement should be changed to "the balance of evidence is in favour of the formula

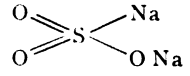


but it cannot be proved with certainty."

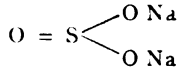
Similar remarks may apply to H – O – O – H or H – O = O – H in preference to



as the formula for H_2O_2, (Vol. I., page 505) ; and also to



in preference to



as the formula of sodium sulphite (Vol. II., page 505), although in the case of the free sulphurous acid the problem is still unsolved.

Yours sincerely,

T. SLATER PRICE.

Municipal Technical School,
Suffolk Street,
Birmingham.

To the Editor of TECHNICS.

DEAR SIR,—With regard to the books you recommend for mechanics I would like to suggest the following as an alternative :—

Solids. Stage III.

Love's "Mechanics," or Routh's "Analytical Statics." Part I.

Routh's "Dynamics of a Particle," and, in default of lectures on attractions and rigid dynamics, Routh's "Analytical Statics." Part II. (Section on Attractions).

Routh's "Elementary Rigid Dynamics." (First three or four chapters.)

Fluids. Stage III.

Besant's "Treatise on Hydromechanics." Part I.

Greenhill's Hydrostatics, in my opinion, is not suitable as a text-book ; it is more a mine of wealth for the accomplished mathematician or the man with a strong engineering bias

Honours, Solids and Fluids.

Routh's "Analytical Statics." Vols. I and II.

Routh's "Rigid Dynamics." Vol. I.

Routh's "Dynamics of a Particle."

Basset's "Elementary Treatise on Hydrodynamics and Sound."

In addition, the student should, if he wants his theoretical knowledge to be any good at all, read Poynting and Thompson's "Heat, Sound and Properties of Matter," and *work through* Perry's "Applied Mechanics."

Yours faithfully,

J. M. CHILD.

Technical College,
Derby.
9th February, 1905.

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To the Editor of TECHNICS.

DEAR SIR,—No satisfactory explanation has yet been given of the resonance produced by the body of a violin. Clearly the definite volume of air contained between the belly or sounding-board and the back of the violin cannot be the cause of the resonance, because many experiments, that of organ pipes for instance, prove that a given column of air can only resound to one pitch or a multiple of that pitch.

The body of a violin resounds equally to all pitches.

Imagine a violin with the back removed. The vibration of the strings is communicated to the belly through the bridge, and sound-waves are given out in all directions. Now the waves produced by one surface of the belly are opposite in phase to those produced at the other, and they must tend to neutralise one another. Replace the back and the sound-post. (The sound-post is a small piece of wood placed inside the violin, touching the belly and the back, and transmits the vibrations of the belly almost instantaneously to the back.) The two surfaces causing sound-waves in the air are now some distance apart, the interference would not be so great and the sound much louder. If you will publish this letter perhaps some of your readers will give me their opinions on this subject.

Yours faithfully,

"Claremont," G. H. BERRY.
Woodberry Down,
London, N.
31st January, 1905.

"TECHNICS" PRIZEMAN.

Award of "Technics" Prize of £200 and Gold Medal.

IN the first number of TECHNICS (January, 1904) it was announced that the competitor who showed the most care, thought, and accuracy during the year's competitions would receive a Prize of £200 in cash together with a Gold Medal. On carefully going through the answers submitted by the various competitors during the year, it has been decided that the Prize shall be awarded to—

Mr. SAMUEL LEES, 1, Trafalgar Street, Broughton, Manchester.

Mr. Lees has obtained four First Prizes (including one prize equally divided between two competitors), one Second Prize, and one Third Prize, together with six Special Honourable Mentions. The answer which obtained each first prize was not only the best sent in for the particular competition, but also witnessed to exceptional ability. We must heartily congratulate Mr. Lees on the result of the year's competitions.

Several other competitors have also shown exceptional ability. Mr. H. H. Francis Hyndman has obtained three First Prizes, one First Prize divided, and ten Special Honourable Mentions.

Mr. J. E. Tytler obtained three First Prizes, one First Prize divided, and four Special Honourable Mentions.

Mr. Percy Robinson obtained three First Prizes.

Mr. Harold Slicer obtained two First Prizes, both divided, one Second Prize, and one Third Prize, together with eight Special Honourable Mentions.

Mr. P. E. Banting obtained four First Prizes and two Special Honourable Mentions.

Mr. B. J. Eaton obtained four First Prizes for papers possessing exceptional merit, on subjects connected with chemical industries, and one Special Honourable Mention.

Mr. S. Irwin Crookes obtained two First Prizes and seventeen Special Honourable Mentions.

In addition, the following competitors obtained successes which call for recognition: A. W. Brierley, I. M. Chippendale, Frank S. Eaton, Arthur Gadd, Edgar P. Hedley, A. G. Lee, C. E. Savage, William J. Williams.

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INDUSTRIAL PROGRESS

THE firm of Messrs. Graham, Morton & Co., Ltd., Hunslet, Leeds, has achieved a notable result in erecting, within the short space of eight weeks, a complete Coal Screening Plant, comprising Screen-House, Tipplers, Jigging-Screens, Picking-Belts with Lowering Arms, Raising and Lowering Gear with Balance Weights, Slack Creepers with Structure, and Gantries for conveying the tubs to and from the screen-house. Altogether an area of 21,300 feet was covered. This work was done for Messrs. J. & J. Charlesworth, of Kilnhurst Colliery, near Sheffield. At this colliery the conveying, elevating, washing and screening of the coal was previously performed partly by hand. The arrangement installed by Messrs. Graham, Morton & Co. performs all the above operations practically automatically.

WE have also received from Messrs. Graham, Morton & Co., Ltd., an illustrated catalogue describing various coal-loading and unloading plants, elevating and conveying plants, aerial rope-ways and transporters. The same firm inform us that they have just obtained an order from Messrs. Jonathan Barker & Co., Esholt, Shipley, for the installation of an overhead tram rail. By the introduction of this plant it has been estimated that a saving will be effected sufficient to pay for its installation within a year.

MESSRS. Hodkin & Jones, Ltd., of Havelock Bridge Works, Queen's Road, Sheffield, have forwarded us an interesting catalogue describing and illustrating their corrugated bar system for fire-resisting floors. This system has obvious advantages when compared with others in which I joists are used: in the first place the cost is somewhat less, in the second place the resulting structure is better calculated to withstand the effects of fire, and in the third place a minimum amount of iron is used. In future numbers of TECHNICS we hope to deal with the subject of Ferro-concrete Construction, which forms one of the most promising advances made in recent years in connection with structural work.

THERE are many industries in which it is important to be able to measure high temperatures with considerable accuracy. In chemical works these measurements are necessary to control the temperatures of vats, stills and furnaces. In connection with annealing furnaces such measurements are no less necessary, although in past times temperatures were estimated merely by the judgment of the fireman, and batches of castings or stampings were frequently ruined. Hardening furnaces, dust destructors, and many other technical processes also require the measurement of high temperatures with accuracy. On the other hand, cold-storage systems require, no less urgently, apparatus for measuring low temperatures. The Cambridge Scientific Instrument Co. have forwarded us their catalogue dealing with Technical Thermometry. The Callendar & Griffiths Resistance Thermometers are perhaps the most accurate, since by their aid any temperature, from the lowest obtainable in practice up to 1,400° C., can be measured with an error not exceeding 0·5 per cent.

MESSRS. Schäffer & Budenberg, Ltd., Whitworth Street, London Road, Manchester, have forwarded us particulars of a standard micrometer which should be of much use to manufacturers of paper, cloth, pasteboard, leather, indiarubber, etc. It will measure with precision the thickness of any substance ranging from $\frac{1}{8}$" down to one two-thousandth part of an inch. The same firm also make a portable gauge-tester, which should be widely used. Boiler inspectors are now required to assure themselves that steam-gauges used in connection with boilers are in correct working order. This result can only be obtained by testing the gauge against a standard. There are two portions of a gauge's range which are most likely to prove in error, and these are precisely the portions where accuracy is most necessary: one is at zero, and the other between the usual working limit and the end of the gauge-scale. The gauge-tester made by Messrs. Schäffer & Budenberg supplies the means for testing a gauge through the whole of its scale.

MESSRS. Kramos, Ltd., Locksbrook Engineering Works, Bath, have favoured us with well-illustrated catalogues describing their high-speed electric drilling machines and also their patent electric resistance pieces. Their resistance pieces are of particular interest, as they combine all the advantages which can be claimed for wire or carbon resistances, with many other advantages which are entirely their own. They are certain to be largely used in the construction of rheostats for large currents, such as are required in connection with searchlights, motor-starting resistances, and in many other cases.

WE are requested by Messrs. Ferranti, Ltd., of Hollinwood, Lancashire, to draw attention to their new catalogues of alternating current ammeters and transformers. These are made in any size up to 6,000 ampères, suitable for any voltage up to 15,000 volts. The ammeters are of the induction pattern, the only moving part being a small aluminium disc. There are no brushes or moving contacts, and the scale of the instrument is very long.

THE Lancashire Dynamo and Motor Co., Ltd., Trafford Park, Manchester, are now winding two induction motors of 360 h.-p. each. The speed is 440 R.P.M., and the pressure is 10,000 volts per phase, the full pressure being applied direct to the stator winding without being transformed down. No other machines have been wound in this country with such a high pressure, namely, 14,000 volts between outers, equivalent to 17,300 volts on a three-phase alternator or motor with a star connection earthed. We hope to give particulars, with illustrations, of these machines in a future number of TECHNICS.

MANUFACTURERS and others requiring steam motor waggons should apply to the Yorkshire Patent Steam Waggon Co., Vulcan Works, Hunslet, Leeds, for their catalogue of Steam Waggons.

THE Lahmeyer Electrical Co., Ltd., are introducing small three-phase motors provided with special ball-bearings. The smaller sizes, up to 1 h.-p., are provided with squirrel cage rotors; the larger sizes can be supplied with or without slip rings as required. These motors range from $\frac{1}{2}$ to 10-h.p., the speed of the smaller machines being 1,410 R.P.M. and that of the larger sizes being 960 R.P.M. All machines made by this firm are guaranteed for one year against bad workmanship and faulty material.

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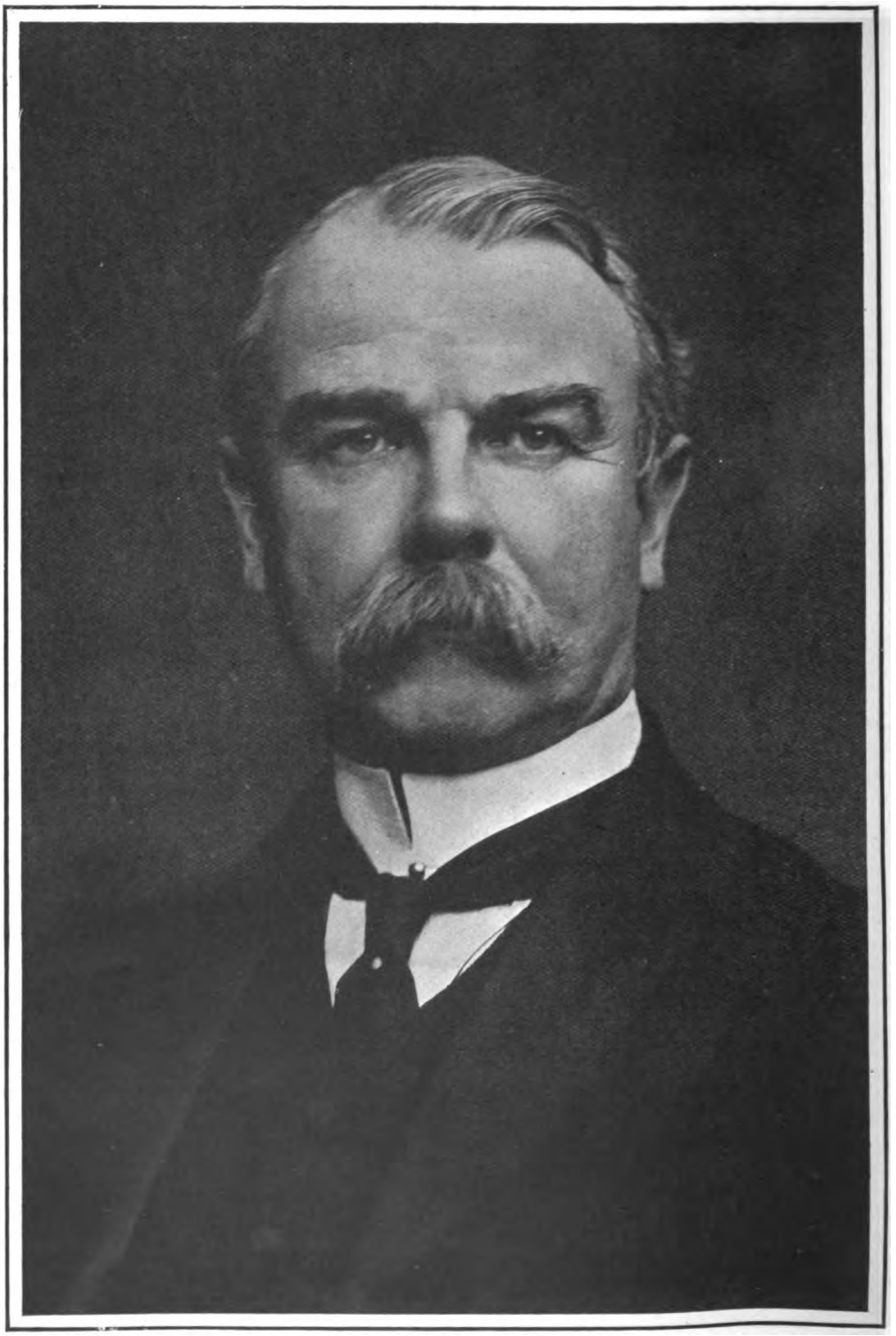

JAMES ALFRED EWING, M.A., LL.D., F.R.S., M.I.C.E.

Photo by Geo. Newnes, Ltd.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. III. APRIL, 1905. No. 16.

PROGRESS OF SCIENCE AND TECHNOLOGY.

THE remarkable development of Japan, which, in a few years, has raised that country from the position of a minor state to that of a power capable of successfully grappling with one of the most formidable European nations, is certainly due to the attention which has there been paid to scientific and technical education. It is somewhat surprising, however, to reflect that the progress made by Japan has been accomplished in little more than a quarter of a century. In 1878 a small band of British professors was invited by the Japanese Government to inaugurate courses of scientific education at the University of Tokio; this band included Professor Ayrton, Professor Perry, and Professor Ewing. After five years it was found possible to select from the students of the University men who could in future carry on the scientific work of the college; nothing could speak more highly for the effectiveness of the teaching of the afore-mentioned professors than this fact. While in Japan, Professor Ewing carried out a number of those researches which have since rendered his name known to all interested in science: we refer particularly to his researches on earthquakes, and on the magnetisation of iron and other magnetic substances. From 1883 to 1890 Professor Ewing occupied the chair of Engineering at the University College, Dundee. From 1890 to 1903 he occupied the chair of Mechanism and Applied Mechanics in the University of Cambridge, and by his influence strove successfully to gain greater attention to applied science at the University. Since 1903 Professor Ewing has held the post of Director of Naval Education at the Royal Naval College, Greenwich. Professor Ewing's contributions to science include a treatise on "Earthquake Measurements" (1883), "Magnetic Induction in Iron and Other Metals" (1891), "The Steam Engine and Other Heat Engines" (1894), "The Strength of Materials" (1899), and numerous papers read before the learned societies. Perhaps one of the most beautiful researches carried out by Professor Ewing was that in which the magnetic properties of iron were explained by the aid of a model consisting of numerous small magnets pivoted on needle points. Reference was made to this research in the March number of TECHNICS (p. 252).

Professor Ewing

IT has been proved conclusively that wireless telegraph signals can be transmitted to a greater distance during the night than during the day; according to Marconi, the greatest distance to which signals can be transmitted by day is only two-fifths of the distance to which they can be transmitted at night. At first sight this would appear to be a very extraordinary result, but recent investigations afford a very simple explanation of it. In wireless telegraphy, electric tubes of force are projected into space from the sparking apparatus at the transmitting station; if these tubes of force reach the receiving station, they affect the coherer or other receiving apparatus in the manner described by Dr. J. A. Fleming in the November number of TECHNICS (page 447). Now, it has been proved that a heated body emits negatively charged particles (or electrons) each possessing about one-thousandth part of the mass of a hydrogen

The "Daylight Effect" in Wireless Telegraphy

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atom. The sun, being at a high temperature, must emit these particles; some of these, when they reach the earth, strike against the gas molecules comprised in the atmosphere, and break these up into their constituent charged atoms. A single electron may dissociate a large number of gas molecules. Hence, in daylight the atmosphere contains numerous charged particles. If an electric field is established in the air during the daytime, the charged particles will travel along the tubes of force.

Now, the electric tubes of force projected from a wireless telegraph transmitting station, as they pass through the atmosphere, will set the charged particles in motion; since the charged particles possess inertia, energy must be absorbed when they are set in motion, and hence the tubes of force must lose energy and finally disappear. At night time the charged particles emitted by the sun are falling on the opposite side of the earth, since they travel in straight lines, like light rays; hence, at night the atmosphere is practically free from charged particles, and is no longer rendered conducting. About two minutes after sunrise the atmosphere has become saturated with charged particles, and the absorption of the electric tubes of force has reached its maximum value. Since light consists of moving tubes of force similar to those utilised in wireless telegraphy, it might appear strange that light is not absorbed by the atmosphere; but in this case, owing to the very short wave-length of the light waves, the field acting on a charged particle changes its direction about 4×10^{15} times a second; therefore, the particle is not set in motion, just as no deflection is produced in a galvanometer by a quickly alternating current. In wireless telegraphy the wave-lengths utilised average about 300 ft., or 9,000 cms., and the field at any point in the line of transmission is reversed about $6 \cdot 5 \times 10^6$ times per second.

The Osmium Lamp

On January 24th Herr Fritz Blau read an interesting paper on the osmium lamp, before the *Electrotechnische Verein* of Berlin. The total energy radiated per second by a hot body is proportional to the fourth power of the absolute temperature of the body. This energy is carried away by waves of all possible lengths; if the energy is plotted as ordinates, the abscissæ being the wave lengths, then the resulting curve shows a peak for a particular wave-length λ_m, such that $\lambda_m T = a$ constant, T being the absolute temperature of the body. Thus the wave-length which carries away the maximum amount of energy is inversely proportional to the absolute temperature of the radiating body; in order to obtain the maximum luminous efficiency, λ_m should be equal to about 0·6 micron (1 micron = 0·001 mm.), corresponding to the yellow-green part of the spectrum; this is the case in sunlight, but such favourable conditions have not been obtained in any system of artificial illumination: in the arc light, $\lambda_m = 1 \cdot 2$ micron. It is obvious that increased luminous efficiency will attend any increase in the temperature of the heated body, for the total amount of energy radiated increases, and a greater proportion of this energy will be carried away by wave-lengths which lie within the range of the visible spectrum. Osmium, generally associated with iridium, is found in platinum ores, and also in gold sand with gold and silver. It is at present obtained by dissolving the platinum or gold in aqua regia, and alloying the insoluble residue with zinc, lead or tin; the osmium-iridium then passes into a finely-divided state, and on being heated in oxygen, the osmium is converted into the tetroxide, while the iridium remains unaffected. Metallic osmium may be obtained by treating the tetroxide with any reducing agent. In making the first osmium filaments, Herr Auer von Welsbach coated platinum wires with osmium, and then evaporated the platinum at a high temperature; it was observed, however, that a platinum-osmium alloy was formed which, when containing more than 4 per cent. of platinum, began to melt while the platinum was being evaporated. In order to prevent this, the finished filament had to be made about five times as thick as the platinum core; as a uniform platinum wire less than 0·02 mm. could not be obtained, osmium filaments thinner than 0·1 mm. could not be made by this process. At present, osmium filaments are made by incorporating finely divided osmium in a paste made with organic binding material, and then squirting the paste under high pressure on to a card which is moved so that the filament is formed into loops of the requisite shape. The filament is then dried and heated in vacuo, when the organic matter becomes carbonised. It is then heated to an intense incandescence by an electric current in an atmosphere rich in steam, and containing a certain proportion of reducing gases; the carbon is thus converted into the dioxide and monoxide, leaving a porous filament of nearly pure osmium. The osmium filament is fused to the platinum sealing-in wires in the electric arc. Osmium

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is brittle when cold, but soft when heated, so that the osmium lamp must be used in a definite position in order to prevent the filament from sagging. At first it was only possible to make osmium lamps for about 37 volts, but soon 44-volt lamps were made, and at present 73-volt lamps are being sold. Quite recently 110-volt lamps have appeared. The life of the osmium lamp is not definitely known, but 5000 hours has repeatedly been exceeded. Lamps requiring only one watt per candle-power burn for several hundred hours without decrease of light, but in practice it is found to be more satisfactory to run them at 1½ watts or more per candle-power. The osmium filament is rather more liable to breakage than the carbon filament, but it has been found that, when the lamps are properly packed, the loss due to breakage in transit does not exceed 1½ per cent. Osmium lamps for mines, requiring only 2 volts, are very efficient.

The Siemens Electrical Pyrometer

THE Siemens Electrical Pyrometer is a platinum resistance thermometer, of which the essential element is a coil of platinum wire wound upon a cylinder of refractory material, and protected by a long, closed tube. For measuring the resistance of the coil, in order to ascertain its temperature, two types of apparatus are made.

The first comprises a differential galvanometer and a set of resistance coils, and gives readings in ohms, from which the temperatures are ascertained by means of a special table supplied with the apparatus (Fig. 1).

The second is a combination of a small D'Arsonval galvanometer and a Wheatstone bridge of circular form with sliding contact, and gives readings directly in Fahrenheit or Centigrade degrees as desired (Fig. 2).

The pyrometer is most accurate; its reading can be depended upon to within a fraction of one per cent. It is also very simple in its action and management, and its working, and may safely be entrusted to the care of an intelligent workman. It finds special application in works where it is necessary to ascertain, from time to time, the temperature of the furnaces, flues, etc.; particularly those in which the processes demand the maintenance of a definite temperature during certain operations.

The method of connecting up the pyrometer with the differential galvanometer is shown in Fig. 1. Starting at the negative pole of the battery, a lead runs to the terminal Z of the pyrometer tube, from which a wire extends to one end of the platinum resistance wire. At this point the circuit divides into two branches. One branch contains a wire running straight back to the pyrometer terminal X', whence a lead B extends to the measuring apparatus, and is connected, through a resistance-box and one coil of the differential galvanometer, with the positive pole of the battery. The other branch includes the platinum resistance wire, a wire running to the

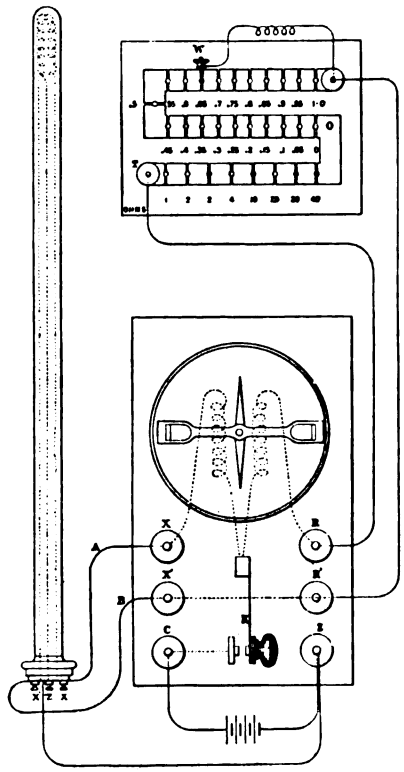

FIG. 1.—SIEMENS PYROMETER, CONNECTED FOR USE WITH DIFFERENTIAL GALVANOMETER.

pyrometer terminal X, and a lead A extending to the measuring apparatus, where it is connected, through the second coil of the differential galvanometer, with the positive pole of the cell. When the resistances of the two branches of the circuit are equal, equal currents will flow through the coils of the galvanometer when the key K is depressed, and no deflection will be produced. The leads A and B from the pyrometer tube to the measuring apparatus are made of the same material and lie close to each other, so that their resistances are always equal, whatever may be their common temperature. The

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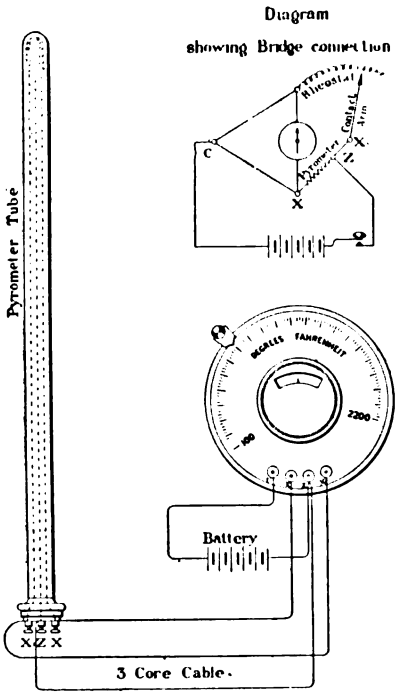

FIG. 2.—SIEMENS PYROMETER, CONNECTED FOR USE WITH WHEATSTONE BRIDGE ARRANGEMENT.
(*The wire from terminal Z of the pyrometer tube is connected to left-hand end of platinum spiral.*)

two wires within the pyrometer tube are also similar in all respects, so that their resistances always remain equal. Thus it appears that the only independently variable resistances in the two branches of the circuit are the platinum spiral in one branch and the resistance-box in the other: the resistance unplugged in the box is thus equal to that of the platinum spiral when no deflection occurs in the galvanometer on depressing the key K.

The direct reading instrument (Fig. 2) comprises a Wheatstone's bridge and the necessary leads to the pyrometer tube. Starting from the positive pole of the battery, a lead extends to the terminal Z of the pyrometer tube, whence a wire is connected to one end of the platinum resistance spiral. This junction forms one angle of the Wheatstone's bridge lozenge (see small diagram, Fig. 2). From it extends a wire running straight back to the pyrometer terminal X_1, whence a lead extends to an arm which makes contact with a helical coil of wire arranged round the edge of a circular dial, thus forming one arm of the Wheatstone's bridge. The conjugate arm of the bridge contains the platinum resistance wire, a wire running to the pyrometer terminal X, and a lead which extends back to the apparatus. The two remaining arms of the bridge are made up of equal and constant resistances, the galvanometer being connected up as shown. When no deflection is produced in the galvanometer on depressing the key, the two variable arms of the bridge must have equal resistances, since the resistances of the remaining arms are always equal; and since the two variable arms comprise equal leads, it follows that the resistance of that part of the helical coil thrown into the circuit by the contact arm must be equal to the resistance of the platinum spiral in the pyrometer tube.

The apparatus described above is made by Messrs. Siemens Bros. & Co., of Woolwich.

The National Physical Laboratory

MANY scientific problems present themselves in connection with industrial processes which can scarcely be solved in the workshop, owing either to the lack of a staff with the requisite scientific skill and knowledge, or to the absence of the necessary instruments of precision. In Germany the *Reichsanstalt*, the *Versuchsanstalt*, and the *Aichungs Kommission* undertake the solution of these problems. In Paris a splendidly equipped laboratory has been established at the *Conservatoire des Arts et Métiers* for the same purpose; in addition, the *Laboratoire Centrale d'Electricité* carries on researches connected with electricity. In America, the *Bureau of Standards* will provide everything required for accurate standardisation. In England, the only institution of the kind is the *National Physical Laboratory*: this institution is unfortunately hampered for lack of funds, so that in the past many interesting and important technical researches have been unavoidably declined. Our national lack of initiative in connection with scientific and technical research is unfortunately so obvious that it is unnecessary to dwell on it here; but the effect of this on our trade can scarcely be ignored, as is shown by the following communication from a Government Surveyor on the West Coast of Africa to Dr. Glazebrook, Director of the National Physical Laboratory.

"The reason why this demand—for accurate surveying tapes—may not have come fully to the notice of the proper authorities in the mother country may, I think, be attributed to the fact that until quite recently there was no place in England where these standards could be obtained (indeed, so far as I am aware, there is no place now) and the Colonies

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have been forced to procure them from foreigners, and the knowledge of the superiority of their workmanship in this direction leads the Colonies to infer that they might be equally advanced in other kindred commodities. I feel I have no need to point out how disastrous this has proved from a national point of view."

In spite of the limitations imposed on the work of the National Physical Laboratory by the absence of adequate pecuniary aid, it is satisfactory to note how much important work has already been carried out. A series of careful tests has shown that Callendar's parabolic formula (connecting the temperature and resistance of a platinum wire such as is used in the platinum resistance thermometer) holds from −200°C. to 1,000°C. A number of standard resistance coils have been constructed with the greatest care. Another subject which has received attention is the effect of wind pressure on structures. Very little is known as to the actual force exerted by the wind on engineering structures—bridges, tall buildings and the like. It is the opinion of many competent judges that the existing Board of Trade rules are unduly severe, but the data on the subject are extremely small. Dr. Stanton has endeavoured to attack the problem by measuring the distribution of pressure and the resultant thrust on small plane areas exposed to a uniform current of air.

The air current, produced by a Blackman fan, is vertical and some two feet in diameter. The surface on which the thrust is to be measured is exposed to the current, being carried at one end of a long lever: the thrust is measured by balancing it against weights at the other end of the lever. The distribution of pressure over the surface is measured by a series of Pitot tubes which are connected by very fine india-rubber tubes to a sensitive water gauge. The other limb of the gauge is connected to the "static pressure" tube of the Pitot tube arrangement.

In this arrangement it can be shown that, if v be the velocity of the current and h the difference of level in the two limbs of the gauge, then $v = k\sqrt{2gh}$ where k is a constant which theoretically is equal to unity. By means of an ingeniously devised anemometer Dr. Stanton verifies this law, obtaining for the constant k the value 1·03. From these experiments the important law was deduced that on similar structures the resultant force due to a uniform wind is simply proportional to the square of the linear dimension. The range of dimensions over which this law has been verified is of course extremely small; if it can be extended to large structures it will enable the resultant forces due to the wind on those structures to be determined from experiments on models, just as the performance of a ship is determined by tank experiments. With a view of extending the law Dr. Stanton is now engaged in repeating the experiments on a large scale in the open air.

Experiments on the cooling curves of iron have been carried out by Dr. Carpenter and Mr. Keeling. A series of iron-carbon alloys have been prepared, the carbon content ranging for 0·01 per cent. to 4·5 per cent. The temperatures were obtained by a thermo-couple, either of platinum and platinum-iridium, or of platinum and platinum rhodium. A galvanometer included in the circuit gives a deflection proportional to the thermo-electric force produced, and from this the temperature of the hot junction at each instant can be obtained. If the cool junction of the couple is kept at a constant temperature, the other junction being enclosed in the cooling mass of iron, curves similar to those given in the February number of TECHNICS (Fig. 1, p. 110) are obtained. This method suffers from the drawback that an extremely sensitive galvanometer cannot be used, since if it were, its deflection would be too great when the iron is at its highest temperature. To avoid this difficulty, one junction of the couple is enclosed in the iron to be examined, and the other junction is enclosed in a piece of platinum. The dimensions of the iron and platinum are equal, and both these substances are initially heated to the same high temperature in an electric furnace and then allowed to cool. No evolution of heat occurs in the platinum as it cools, and if none occurred in the iron the two substances would cool at practically equal rates, and the galvanometer would show no deflection. At each of the "arrest points" of the iron, however, an evolution of heat occurs, and therefore deflections of the galvanometer are produced: since a very sensitive galvanometer can be used, its deflection at any instant being proportional to the difference between the temperatures of the cooling masses of iron and platinum, it follows that small evolutions of heat in the iron, which might otherwise escape notice, can be readily observed. When the iron is nearly pure a considerable evolution of heat occurs at 900°C. (Ar_3 for pure iron) corresponding to the transformation from γ to β iron. A smaller and comparatively gradual evolution of heat commences

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Substance.	Condition.	Disruptive Voltage.	Ratio of Difference from Mean, to Mean.	Thickness. (Millimeter.)	Volts per Millimeter.	Punching Pressure. Pounds.	Bending Test. (Cylinder Diameter.)
			Per cent.				
Press-spahn. . . .	*a*	2,180	9	0·23	9,500	55	
	b	2,330	6		10,000	57	$\frac{1}{16}$ in.; >10
	c	2,330	6		10,200	27	$\frac{3}{4}$ in.
Press-spahn . . .	*a*	2,920	13	0·56	5,200	106	
	b	3,550	3		6,300	105	$\frac{1}{16}$ in.; 6
	c	3,670	7		6,550	79	1 in.
	d	3,330	3		5,950	40	$2\frac{1}{2}$ in.
Press-spahn . . .	*a*	6,650	2	1·61	4,150	>150	
	b	>9,000			>5,600	>150	about 5 in.
	c	>9,000			>5,600	>150	about 8 in.
Press-spahn and Standard Varnish	*a*	3,610	8	0·34	10,500	57·5	
	b	7,120	12		21,000	74	$\frac{5}{8}$ in.
	c	>9,000			>26,000	67	1 in.
	d	>9,000			>26,000	60	$1\frac{3}{4}$ in.
Manila Paper . . .	*a*	1,540	8	0·28	5,500	62	
	b	1,540	2		5,500	25	$\frac{1}{2}$ in.
	c	1,590	5		5,700	20	1 in.
Manila Paper . . .	*a*	1,620	4	0·38	4,300	69	
	b	1,920	4		5,100	41	$\frac{1}{16}$ in.; 4
	c	1,840	5		4,800	24	$1\frac{3}{4}$ in.
Manila Paper and Standard Varnish	*a*	1,800	2	0·34	5,300	54	
	b	3,400	8		10,000	47	1 in.
	c	4,340	8		12,700	42	2 in.
	d	4,180	9		12,300	37	$2\frac{1}{2}$ in.
Waterproof Board .	*a*	2,420	2	0·29	8,300	62·5	
	b	3,720	7		12,800	67	$\frac{1}{16}$ in.; >10
	c	3,630	11		12,500	34	1 in.
Waterproof Board .	*a*	3,300	4	0·44	7,500	94	
	b	4,480	17		10,200	102	$\frac{1}{16}$ in.; >10
	c	5,200	10		11,800	57	1 in.
Oiled Cloth . . .	*a*	4,580	4	0·22	21,000	29	
	b	5,110	20		23,000	27	$\frac{1}{4}$ in.
	c	4,650	14		21,000	24·5	$\frac{5}{8}$ in.
	d	3,940	12		18,000	19	1 in.
Red Oiled Paper . .	*a*	6,600	6	0·25	26,000	30	
	b	6,850	11		27,000	34	$\frac{1}{2}$ in.
	c	7,900	13		31,000	37	$\frac{1}{2}$ in.
	d	6,940	8		28,000	28	$1\frac{1}{4}$ in.
Black Oiled Board .	*a*	5,320	2	0·30	17,700	59	
	b	5,460	8		18,200	61	1 in.
	c	6,170	3		20,600	55·5	2 in.
	d	4,870	4		16,200	33	$2\frac{1}{2}$ in.

at 765°C. (Ar_2), corresponding to the transformation from β to α iron, the iron becoming magnetic when cooled below this temperature. When the iron contains an appreciable percentage of carbon, a third evolution of heat occurs at 690°C (Ar_1) corresponding to the segregation of the eutectic (pearlite). A small and gradual evolution of heat occurs at 580°C.: this point has been denoted by Ar_0, and corresponds to minimum magnetic permeability for fields of a certain strength. The results obtained show a close agreement with modern theory, but several unexplained changes occur which show the need of further research.

TABLE I. contains the results of experiments carried out at the National Physical Laboratory, on various insulating substances in general use. In this table— **Insulation**

a, indicates that the specimen had not been heated.

b, indicates that the specimen had been heated for three months to about 75°C.

c, indicates that the specimen had been heated for three months to about 100°C.

d, indicates that the specimen had been heated for three months to about 125°C.

It becomes evident that the insulating properties are improved by heating to 75°C.; they

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are not seriously affected by heating to 100°C., but a marked deterioration is produced by heating to 125°C. The bending tests were carried out by bending the specimens round cylinders of different diameters, commencing with large and proceeding to smaller cylinders, and noticing the diameter of the cylinders at which breakage occurred.

Heating of Magnet Coils

ANOTHER important research carried out at the National Physical Laboratory relates to the temperature of dynamo and motor field-magnet windings. The life of the windings will depend on whether, during working, they are overheated or not. The danger from overheating the windings will depend on the highest temperature attained by any part of the winding, and as the hottest coils will obviously be those in the middle of the winding, it is not of much use to measure the temperature of the outer and coldest coils with an ordinary thermometer. The average temperature of the windings can be determined by measuring their resistance (1), at the temperature of the air, which can be measured, and (2), after the coils have carried their working current for such a time that their temperature has become constant. Then remembering that the increase in resistance of copper is 0·4 ohm for each 100 ohms at 0°C., it is easy to calculate the mean temperature attained by the windings. Several makers gave their help, and wound a number of their field coils of the ordinary pattern, but containing thermo-junctions of iron-eureka wire at various positions in the winding. In the case of one coil it was found that when carrying a current of 8·1 amperes in the laboratory, the mean temperature was 113°C., and the maximum was 136°C., the maximum being thus 20 per cent. greater than the mean temperature. When the same coil was used on a 500 kilowatt machine using the same current, the mean temperature was 82°C., and the maximum was 103°C. (these figures are lower than those obtained in the laboratory, owing to the fanning action of the armature), showing that the maximum was 25 per cent. greater than the mean temperature.

High Temperature Thermometry

A GENERAL investigation into the methods of attaining and measuring very high temperatures, and, in particular, the elaboration of some form of electrical pyrometer for measurement of temperatures up to, say, 1800°C., has been commenced at the National Physical Laboratory. As it has been conclusively shown that no metals hitherto used in pyrometers will continue to withstand for any length of time the combined effect of the action on them of the furnace vapours and gases by which they are surrounded, at high temperatures such as 1500°C., attention has been turned to the various oxides of the alkaline earths and allied groups, with a view of elaborating from some mixture of these, such as is used in Nernst lamps, substances possessing sufficiently unalterable physical properties to enable them to be used as the basis of a system of high temperature measurement. As stated in the report of the director for 1904, the existence of large thermo-electro motive forces between rods of some of these earths, made up and treated much as ordinary thermo-junctions, has been established by experiments at high temperatures, and a further investigation of this phenomenon and a study of the resistance of such rods by appropriate methods will form the basis of the main investigations of the department during the immediate future.

Accuracy of Kelvin Balance for Alternating Currents

A SET of five non-inductive resistance frames (each 50 ohms and to carry 2 amperes) was constructed. By means of these, comparisons were made, both with direct and alternating current, of one of the standard Kelvin electrostatic voltmeters and one of the Kelvin balances (to 100 amperes). The agreement was quite satisfactory, and this disproves (for ordinary frequencies) the allegation that, when used with alternating currents, the accuracy of the balance is affected by eddy currents in the metal parts near the coils.

Standard Cells

THE investigation of certain anomalies of Clark and cadmium cells has been continued at the National Physical Laboratory. Special four-limb cells were constructed, designed so as to contain three different samples of any one element of the cell. In this way the instability of the samples was determinable. Mercurous sulphate was the first substance to be investigated, the observations of previous years indicating its behaviour to be most unsatisfactory. The investigation proved the sulphate, as ordinarily prepared, to be quite unsuitable for standard cells, and a standard method of preparation was sought. Three methods proved to be successful. The first of these is a modification of one due to Divers and Shimidzu, the salt being prepared

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with fuming sulphuric acid and mercury. The second is a precipitation method, while the third is an electrolytic method, due to Professor H. S. Carhart, Mr. G. A. Hulett, and Dr. F. Wolff. Very satisfactory results were obtained. Six cadmium cells, prepared with samples of mercurous sulphate so made, were taken to the United States by Dr. Glazebrook in September, the object being to compare their E.M.F.'s with those of other cells constructed by Professor Carhart. Unfortunately, the cells changed in transit; the reason for this is unknown, but will be investigated. There is little doubt, however, but that a depolariser can now be prepared, such that the E.M.F.'s of cells prepared with samples manufactured at different times will not differ by more than a few hundredths of a millivolt. With purchased samples of mercurous sulphate, cells were prepared having E.M.F.'s differing by more than two millivolts.

An investigation has also been made to determine the difference, if any, of E.M.F. between the H form of cell and the tube or Board of Trade form. Since 1892 the H form has been assumed to have a smaller E.M.F. by 0·0004 volt. Cells combining the two forms were constructed, and observations made on both Clark and cadmium cells. The results showed conclusively that no difference so great as four ten-thousandths of a volt exists; the difference, if any, must be very small.

A preliminary report on the anomalies of standard cells was presented to Section A of the British Association at Cambridge.

In the near future it is hoped that the investigation will be completed, and a satisfactory specification for both Clark and cadmium cells prepared. The various objections against both kinds of standards when subjected to a fluctuating temperature will also receive attention.

Improvements in Throttle Valves

The reason for the greatly improved running of a petrol motor at light loads, due to the provision of a device for reducing the lift of the induction valves instead of one for reducing the opening of the ordinary throttle valve, is not very apparent on the surface, although the actual improvement is very noticeable. The reason can be found by fully investigating the actions that take place on the two sides of both the induction and the throttle valves. Such an investigation shows that the throttle, as ordinarily fitted, is capable of improvement without complication, so that even if "variable lifts" are not generally adopted, they will have done some good by indirectly leading to throttle valve improvements.

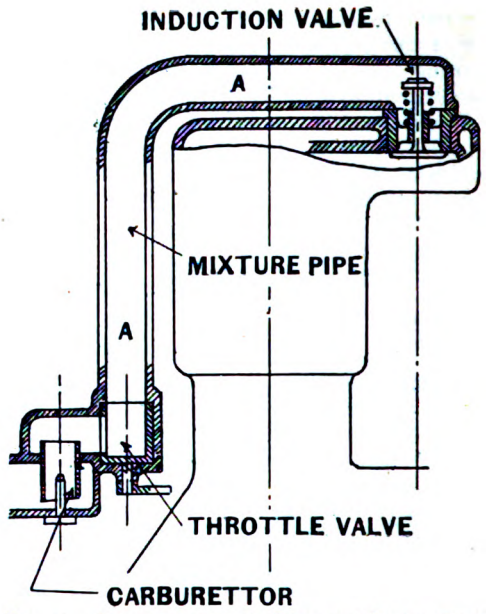

Fig. 3.—Arrangement of Petrol Motor with throttle valve at a distance from induction valve.

It is usual for the manufacturers of multi-cylinder motor car engines to use one throttle for all the cylinders, and to place this close to the carburettor. It will be seen that there is a considerable volume of mixture pipe between the throttle valve and the induction valve, and the volume of pipe so placed has a considerable effect on the running of the engine when throttled.

Take the case of a single-cylinder engine; when the throttle is nearly closed, the motor on its suction stroke first draws gas from this space until there is a depression, before any appreciable quantity of fresh mixture passes through the throttle. If the volume of this space is considerable (as at A, Fig. 3), the motor draws all or most of its charge from A, with the consequence that it has to use stagnant mixture; and, as the suction stroke occupies only one quarter of the total time, and mixture can flow through the throttle all the time, to run the engine on light load requires a very small throttle opening indeed, as there is a comparatively large pressure difference between the two sides of the throttle valve, producing high velocity of gas through the port in a practically continuous flow.

As only a small quantity of mixture is

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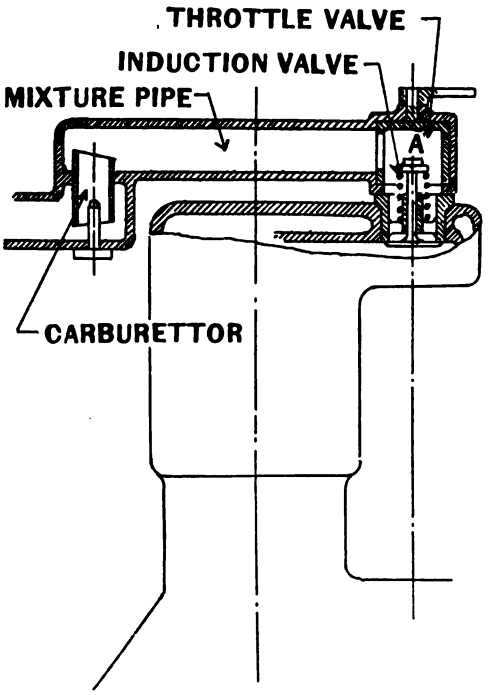

FIG. 4.—ARRANGEMENT OF PETROL MOTOR WITH THROTTLE VALVE NEAR INDUCTION VALVE.

required, the air passes the jet as a continuous stream at a small velocity, a condition rendering correct carburation extremely difficult. If, on the other hand, the throttle is kept as close as possible to the induction valve, as in Fig. 4, a very small movement of the piston produces the necessary depression in the small chamber A, with the result that the mixture is drawn almost directly from the carburettor into the cylinder without stagnation; and as there is no large reservoir to be filled after the end of the suction stroke, gas is in motion practically only during the suction stroke, producing intermittent "puffs" of air past the jet at a much higher velocity than in the previous case, resulting in better carburation and consequently more steady running and higher economy.

The same considerations apply equally well to multi-cylinder engines; in this case, to obtain the best results, it is necessary to use separate valves for the different cylinders, all being carefully adjusted to admit exactly equal quantities of gas in all circumstances.

THE area of full throttle opening necessary for the average high-speed petrol engine is equal to one-twelfth the area of one cylinder, and this corresponds to a mean gas velocity of 160 feet per second, with a mean piston speed of 800 feet per minute. The shape of the port requires a little consideration, and depends on several factors. To regulate the running of the engine well, the throttle must be very sensitive when the engine is on light loads, and should therefore not reduce the quantity of gas in proportion to the movement of the valve, but rapidly at first and subsequently more gradually.

Proportions of Throttle Ports

It is apparent that the weight of gas passing the throttle varies, not only in proportion to the area of opening, but also with the rate of flow due to difference of pressure on the two sides of the valve, and that at constant engine speed the pressure difference increases as the port area is reduced, so that in a throttle for power regulation at constant speed the area of opening will decrease more rapidly than the power developed, assuming the latter to vary directly as the weight of gas passing the throttle.

Further, the gas required to drive an engine at maximum torque varies directly as the speed, so that for full power the necessary area of port varies directly as the speed; it follows that to reduce the speed of an engine by throttling, the area of opening must be reduced in greater proportion than the speed.

If the throttle is far from the induction valve, as in Fig. 1, a small opening will admit more gas than if it is close, as the gas will be passing during a longer total time: thus the volume of the mixture pipe has also an effect on the shape of the ports, and the aperture of the throttle need not be so finely adjusted if it is close to the induction valve.

The approximate shape of a throttle port to fulfil the necessary conditions is shown in the diagrams, Figs. 5, 6, and 7; as it is closed in equal increments its area is reduced, first rapidly, then more gradually, until the minimum opening which will run the engine

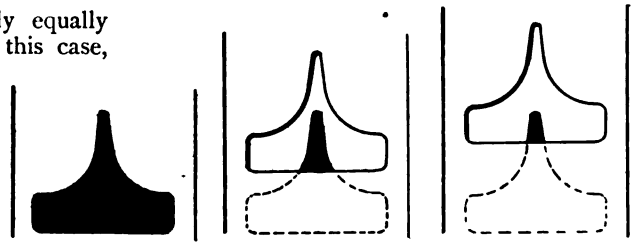

FIG. 5. FIG. 6. FIG. 7.

SHAPE OF THROTTLE PORT.

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is reached; finally it closes somewhat suddenly, to avoid passing too small a quantity of mixture to cause an explosion.

The curve shown in Fig. 8 illustrates the rate of closing for the valve port.

THE differential or "balance" gear is an essential part of all self-propelled rubber-tyred road vehicles which have more than one

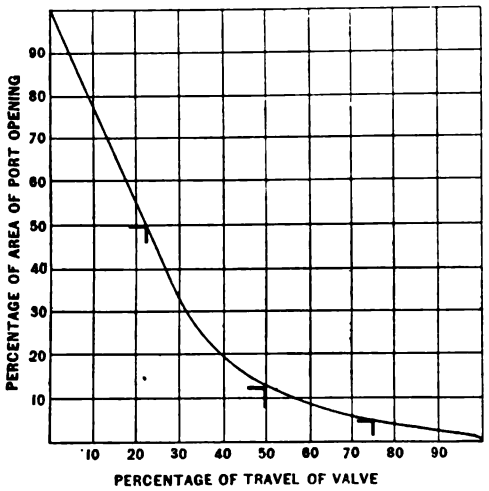

FIG. 8.—CURVE SHOWING AREA OF THROTTLE PORT FOR VARIOUS POSITIONS OF VALVE.

wheel driven. The commonest form of differential gear was illustrated on page 57 of the present volume,* in the article on "Epicyclic Trains" by Mr. Thornton Knowles; but this form is being displaced by the spur-wheel type shown in Fig. 9. The action is similar in both cases: the bevel pinions which drive the two sides are replaced each by two wide spur pinions gearing with each other for half their widths; the other halves gear, one pinion with one side and the second with the other side, thus obtaining the same action as in the bevel type.

Differential Gears

The spur type has several advantages over the earlier bevel type. It is easier and cheaper to manufacture; but the principal advantage lies in the elimination of bevel gears, thus doing away with all end thrust, allowing the gear to act more freely and reducing the wear.

The outside diameter of the gear casing can be kept of a reasonable size by reducing the number of teeth in the pinions. As few as ten teeth can be used, providing a suitable tooth form is adopted, and the gears are made of good material and are proportioned to keep all stresses within permissible limits.

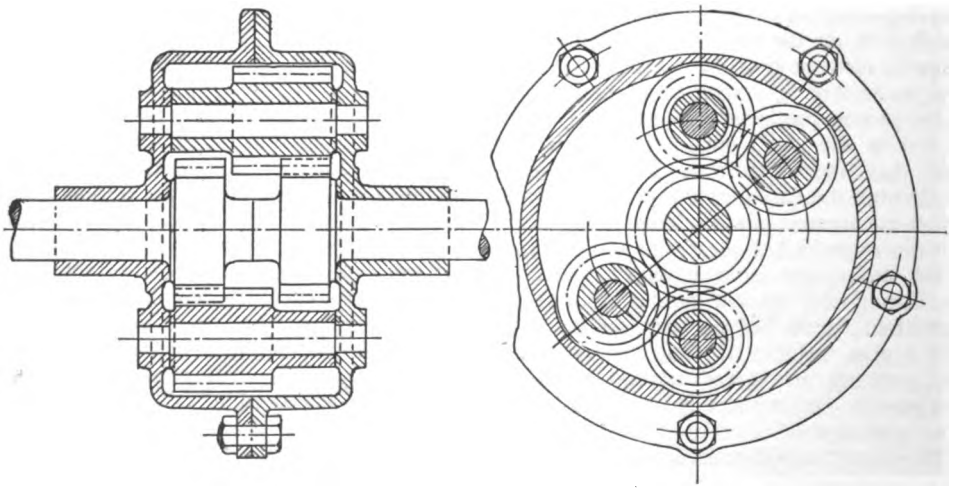

FIG. 9.—SPUR-WHEEL DIFFERENTIAL GEAR FOR MOTOR-CARS.

ON examining the petrol engines at the recent great motor-car exhibitions, one was struck by the apparent uncertainty that exists amongst manufacturers as to the best position

* TECHNICS, Vol. III., No. 13, January, 1905.

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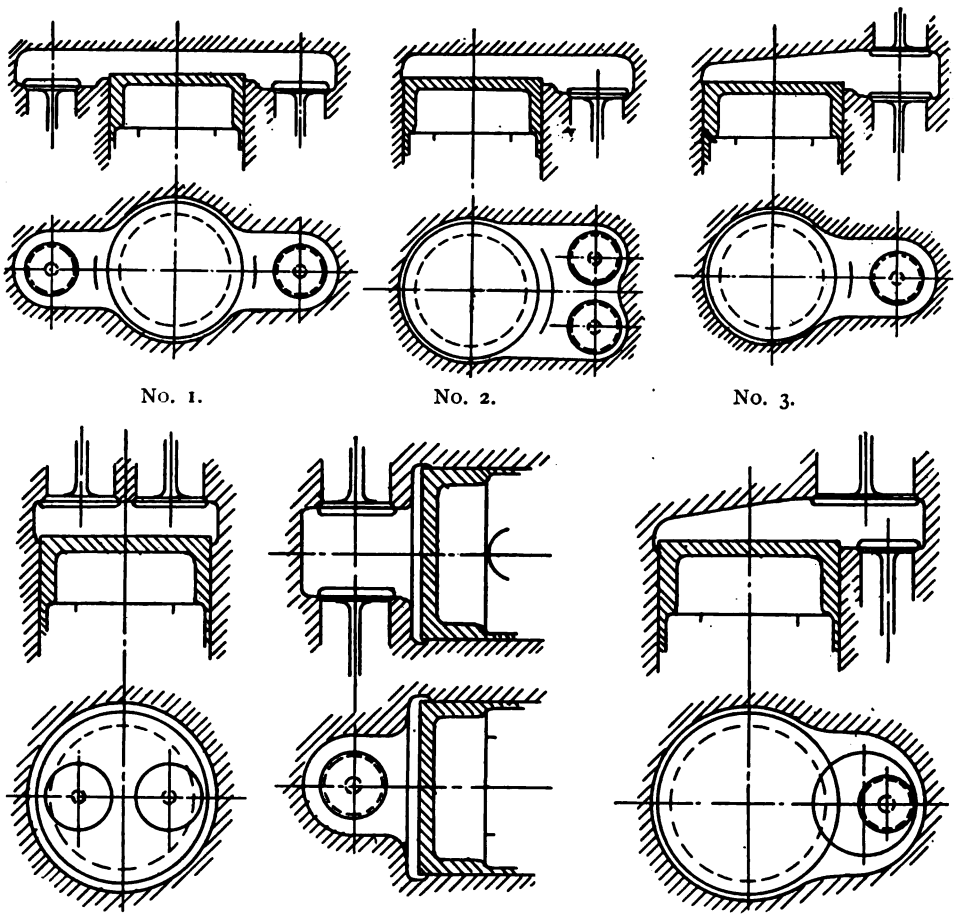

FIG. 10.—TYPICAL POSITIONS FOR INDUCTION AND EXHAUST VALVES.

for the induction and exhaust valves, and even the area of port opening necessary for the maximum efficiency.

Valves in Petrol Engines

The various arrangements may be divided broadly into five main types, as shown in Fig. 10; they are arranged roughly in order of frequency, No. 1 being the favourite. This is undoubtedly not the order of merit for heat efficiency, No. 1 being certainly one of the worst, owing to its excessive cooling surface and irregular form, its redeeming feature being probably that it makes a symmetrical and easily accessible engine.

The arrangement shown in No. 4 probably gives the highest heat efficiency, owing to its regular form and small cooling surface. This form is used in the Maudsley engines, but would no doubt be found inconvenient for small cylinders.

No. 5, the Wolseley arrangement for horizontal engines, is good; its only bad feature is that the temperature of the incoming charge is increased by passing over the hot exhaust valve, but this, of course, lengthens the life of the exhaust valve by keeping it cool.

Nos. 2 and 3 have about equal heat efficiencies, No. 3 being perhaps the better, while No. 2 makes the neater engine.

For a combination of, or rather compromise between all the good points, it is probable that a modification of No. 3 would be found best. This is shown in No. 6.

It has been demonstrated that in the average engine with equal diameter of valves, the induction valve is too small, and the exhaust valve unnecessarily large. No. 6 has a fairly good form for heat efficiency; the exhaust valve, being comparatively small, is placed in a small pocket, where it does not affect the temperature of the bulk of the incoming charge, yet is cooled sufficiently to

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prevent over-heating and pre-ignition. The induction valve can be of ample size, and the charge is not diminished by having to pass to the cylinder by a tortuous passage, as in Nos. 1, 2, and 3. It also makes a convenient engine, and certainly gives the practical maximum of volumetric efficiency.

Many other valve arrangements may be found in individual cases, but do not appear to offer any material advantages over these types.

Pneumatic Valve Control

THE Winton petrol motor-cars are fitted with an unusual form of combined hand and governor control on the induction valves, which renders the engine very flexible and easily controlled. The arrangement is shown somewhat diagrammatically in Fig. 11.

It consists of a small cylinder, in which works a piston attached to the induction

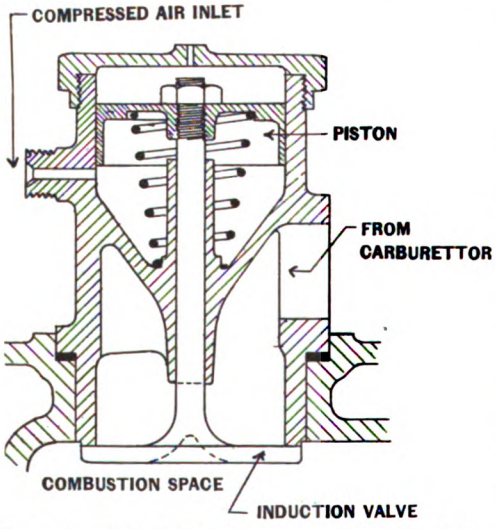

FIG. 11.—ARRANGEMENT FOR PROVIDING COMBINED HAND AND GOVERNOR CONTROL ON INDUCTION VALVE.

valve. Air under pressure, supplied from a small pump driven by the engine, is forced into this cylinder and opposes the opening of the valve. A bye-pass to the atmosphere is arranged to regulate the air pressure, so that the induction valve can be set to open at any desired vacuum in the combustion space of the engine, thus giving a very sensitive "variable lift" device having one great advantage over the mechanical variable lift, inasmuch that it forms an adjustable speed governor as well. It will be seen that, if the engine slows down, the pump will deliver less air, so that the pressure drops, owing to the bye-pass, allowing the induction valve to open earlier and further, and admit more gas, thus forming a fairly sensitive governor.

When it is desired to run the engine at full power, the bye-pass lets off all the pressure generated by the pump, so that the valve acts as an ordinary atmospheric valve, the usual spring being fitted to keep it on its seat; but the chamber over the piston forms a dash-pot, rendering the action of the valve practically silent.

If the bye-pass be completely closed, the pressure of air is sufficient to prevent the valve opening, even against the full suction of the engine.

Constitutional Formulæ of Ammonium Salts

IT is proposed by Dr. J C. Cain to consider the chlorine in ammonium chloride as being trivalent, $H_3N = ClH$, and the oxygen in ammonium hydrate as tetravalent, $H_3N = OH_2$, with the view of explaining: the differences between solutions of ammonia and of the alkaline hydroxides; the existence of isomeric quaternary ammonium salts; the formation of diazonium and of metal-ammonium compounds; diazotisation and the reduction of diazonium derivatives to hydrazine. (*Mems. and Proc. Manchester Lit. and Phil. Soc.*, 48, No. 14.)

Purgative Properties of Anthraquinone Compounds

SINCE A. Tschirch suggested in 1898 that the purgative action of rhubarb, senna, aloes, and frangula bark is due to oxymethylanthraquinones and their glucosides, many artificial compounds allied to anthraquinone have been shown to have such action. Purpuroxanthin (dioxyanthraquinone), anthragallol, with three other trioxy anthraquinones, alizarinbordeaux (tetraoxyanthraquinone), purgatin, the diacetyl derivative of 1:2:7 anthraquinone and exodin (diacetylrufigallic tetramethylether) are active.

New Oxidising Bacterium

A NEW oxidising bacterium which reduces the cupro-potassic reagent, and is different in form and appearance from "Mycoderma Aceti" and the bacterium of sorbose, has been separated by R. Sazerac from wine vinegar. It grows in neither meat nor potato broth, but grows well on glycerinated gelose. Isolated on plates of the latter at 2 per cent., it gave with glycerin broth, homogeneous cultures having reducing power at ordinary temperature It rapidly oxidises glycerin into dioxyacetone. (*Bull. Soc. Chem. de Paris*, 29, 16.)

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BALLISTICS OF MODERN RIFLES.

PART II.—INTERNAL BALLISTICS.

Continued from No. 13, p. 16.

By R. H. HOUSMAN, B.Sc., M.I.E.E.

THERE are two ways in which an explosive may be burnt in a cartridge, neither of which is found in actual practice:—(*a*) At constant volume, and (*b*) at constant pressure. In all actual cartridges the pressure rises at first, and then falls whilst the combustion is proceeding; the increase in the volume to be filled with gas becomes more and more rapid as the bullet accelerates, whilst the rate at which gas is evolved continually decreases owing to the reduction of the burning surface; the maximum pressure being reached when the two rates are equal. The two extreme cases, however, may be taken as indicating the limits between which all actual examples are found.

In explosion at constant volume the whole of the explosive is consumed before the bullet begins to move, so that the maximum pressure is reached before the volume begins to increase. This, whilst requiring an enormous chamber volume to keep the pressure within practicable limits, has the advantage that the pressure is definitely fixed and cannot be increased by rise of temperature, weight of bullet, or strength of cap, etc. The disadvantage is that the efficiency obtained from a given barrel is very low, and the gas consequently escapes at a very high temperature. Explosion at constant volume marks the extreme limit of the tendency to control pressure mainly by excessive chamber volume. The results are rapid heating of the barrel, and increased recoil and muzzle blast; further, a most unwieldy cartridge is required to obtain a given velocity. The pressure diagram is shown in curve AA, Fig. 1.

Case (*b*) (*i.e.*, explosion at constant pressure) is the other extreme which cannot be realised in practice, but which, if it could be attained, would have the following advantages:—

Maximum efficiency.

Maximum output from a given barrel when maximum and muzzle pressures are specified.

Minimum heating of the barrel; and, lastly, a very small and compact cartridge.

This case is illustrated in curve ABB, Fig. 1. The contrast of these curves is at once evident. In curve AA the pressure falls rapidly from the maximum, but is well maintained towards the muzzle; whilst in curve ABB the maximum pressure is maintained constant whilst the explosive is burning, and then falls much more rapidly than in the other case. If Fig. 1 is taken to represent the 0·303 Service barrel with the pressure at the breech limited to twenty tons per square inch, and that at the muzzle to three tons, the bullet weighing 215 grains; then the indicated energy required to give a velocity of

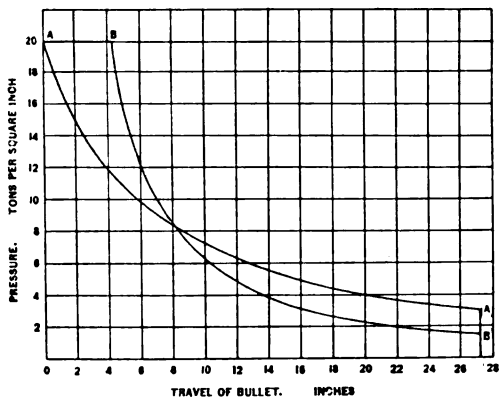

FIG. 1.—CURVES SHOWING PRESSURE FOR VARIOUS POSITIONS OF BULLET, WHEN CHARGE IS EXPLODED (*a*) AT CONSTANT VOLUME (CURVE AA) AND (*b*) AT CONSTANT PRESSURE (CURVE ABB).

0·303 *Service barrel; breech pressure = 20 tons per square inch; muzzle pressure = 3 tons per square inch; weight of bullet = 215 grains.*

2,050 feet per second is about 2,700 foot-lbs., assuming a mechanical efficiency of 75 per cent.

In case (*a*) the capacity of the cartridge case required is 0·83 cubic inch. This is more than four times the capacity of the Service 0·303 cartridge case.

In case (*b*) the volume is only 0·06 cubic inch, or about one-fourteenth of the capacity in case (*a*). The charge required in (*a*) is 52·2 grains; that required in (*b*) is 23·6 grains.

It is supposed, in case (*b*) that the cordite completely fills the case, and that the surface increases with the velocity of the projectile. Both of these conditions are impracticable, but the nearer we can approach them, the more efficient will be our cartridge. For example, the maximum available energy of cordite is about 235 foot-lbs. per grain. In case (*a*) the indicated energy is only 51·7 foot-lbs. per grain, or 22 per cent. In case (*b*) the indicated energy is over 114 foot-lbs. per grain, or nearly 49 per cent.

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In the above calculations it has been assumed that the expansion curve is of the form $PV^{\gamma} = \text{constant}$. The value of γ has been taken as 1·4 in both cases, although, of course, some of the energy has been extracted from the gases in case (*b*) by increase of volume at constant pressure. This, however, may be considered as balanced by the greater loss of heat to the sides of the case in (*a*). In both cases the index 1·4 represents a curve falling considerably below the adiabatic, which appears to have an average index of about 1·2, the difference being due to loss of heat to the barrel. An examination of the expansion curves given by cordite so finely divided as to burn before the bullet moves, shows that the value of γ increases gradually as expansion proceeds from 1 up to about 1·4; it is, therefore, assumed that $\gamma = 1$ up to the point of maximum pressure.

It would appear that the reaction caused by the explosion does not take place instantaneously, the evolution of heat extending over a certain interval of time. An experiment intended to test this point was made as follows:—Cartridges were loaded with cordite in the form of fine dust without any vaseline; these gave explosion at constant volume, and the maximum pressures were nearly equal with two bullets, one of which was double the weight of the other; yet the pressure fell more rapidly with the light than with the heavy bullet. This seems to show that more heat was evolved with the heavier bullet, owing to the longer time it took to traverse the barrel, in spite of the greater loss of heat to the barrel.

Fig. 2 shows the pressure curves given by 0·303 cartridges in a "short lead" barrel, the weight of the bullet being 215 grains, and that of the charge 30 grains. Three thicknesses of strand cordite were used, *viz.*:—0·023 inch diameter, 0·033 inch, and 0·039 inch; the fourth curve is that given by flat strip 0·185 inch × 0·022 inch.

From these curves the great advantage of an explosive which has a large final surface will be seen, the velocity given by the flat strip being practically the same as that of the 0·033 strand, which is the thickness used for the Service cartridge, the pressure being only 14·4 tons as against 17·9 tons. The lower pressure is compensated by the comparatively early stage at which combustion is completed. With the flat strip the whole of the cordite is burnt before the bullet has travelled 12 ins. With the 0·033 strand a core 0·006 inch in diameter remains unburnt when the bullet leaves the muzzle, and most of this is consumed subsequently. An early combustion of the

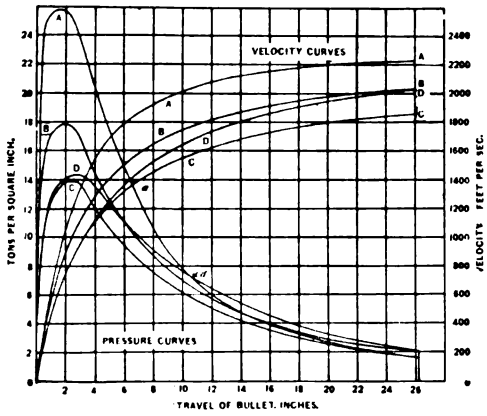

FIG. 2.—PRESSURE CURVES FOR 0·303 SHORT LEAD RIFLE, WITH 215 GRAIN BULLET AND VARIOUS THICKNESSES OF CORDITE.

Particulars of the various curves are given in Table I.

A, all cordite burnt at *a*. B has 0·006 unburnt at muzzle. C has 0·014 unburnt at muzzle. D, all cordite burnt at *d*.

cordite may be obtained by reducing the thickness of the strand; but in this case, the maximum pressure is increased to an inconvenient extent, as shown by the curve for the 0·023 strand cordite.

The 0·039 inch strand is unsatisfactory at a temperature of 60°, owing to a thickness of about 0·014 inch being left unconsumed when the bullet leaves the muzzle; yet it gives satisfactory results in tropical climates, where the acceleration of the combustion of the cordite by temperatures of 120° Fahr. and upwards makes its behaviour very similar to that of the 0·033 inch strand at 60°. Table I.

TABLE I.—DATA REFERRING TO CURVES IN FIG. 2.

	Velocity.	Muzzle Energy.	Indicated Energy.	Mechanical Efficiency.	Pressure.
	ft./sec.	ft.-lbs.	ft.-lbs.	Per Cent.	tons sq. in.
A.—30 grains of 0·023 in. strand	2,247	2,404	3,276	73·5	25·8
B.—30 grains of 0·033 in. strand	2,043	1,988	2,627	75·7	17·9
C.—30 grains of 0·039 in. strand	1,876	1,676	2,000	83·8	14·05
D.—30 grains of 0·105 in. × 0·022 in. flat strip .	2,034	1,970	2,542	77·5	14·4

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shows the results of the four charges mentioned above, and illustrates some interesting points. For example, it is clear that increase of pressure, by accelerating the combustion of the cordite, increases the efficiency, since the indicated energy per grain of cordite is 109 ft.-lbs. for the 0·023 inch thickness, as compared with 88 ft.-lbs. for the 0·033 inch, and 73 ft.-lbs. for the 0·039 inch. The friction is seen not to be constant, as is sometimes assumed, but to increase with the pressure, which is accounted for by the increased "setting up" of the bullet and the greater pressure of the surface of the bullet against the sides of the bore with high pressures. This results in the friction being nearly proportional to the pressure, and the mechanical efficiency being nearly constant. With strand cordite of various thicknesses, the maximum pressure for a given charge seems to be approximately proportional to the initial surfaces; thus the initial surfaces are:—13·2 square inches for the 0·023 inch, 9·2 square inches for the 0·033 inch, and 7·8 square inches for the 0·039 inch; whilst at the point of maximum pressure the surfaces of all three are nearly equal. The initial rate of rise of pressure is in proportion to the surfaces, since it is determined by the value of *burning surface ÷ net volume of case*, and hence, the thinner the strands the sooner is the maximum pressure attained, and therefore the higher the pressure required to give the critical velocity.

Fig. 3 shows the effect of increasing the chamber volume of a cartridge, the thickness of cordite being the same in each case. The pressure gun in which these cartridges were fired had a loose ring, which could be placed at the back of the chamber so that a special cartridge, made longer in the body than the Service cartridge, could be fired under exactly the same conditions as the usual 0·303 cartridge. The volume of the long case was 0·231 cubic inch as against 0·193 for the Service cartridge—an increase of about 20 per cent. It will be seen from Table II. that to obtain the same velocity in the long case, an increase of about 10 per cent. in the charge was required; but in spite of this increase of charge, the pressure for the same velocity is considerably lower with the longer case. It will also be observed that with the long cases the point of maximum pressure is further forward than with the short ones, and the pressure falls less rapidly towards the muzzle. This, of course, would be an advantage if it were not counterbalanced by the lower efficiency and consequently more rapid heating of the barrel by continuous firing. It will thus be seen that all the good effects of enlarging the chamber volume may be obtained, without the disadvantages, by substituting flat strip for strand cordite in the ordinary 0·303 cases. Table II. shows the results given by the charges corresponding to the pressure curves in Fig. 3. The reduction of efficiency with the larger chamber is due, partly to the slower combustion of the cordite under the lower initial pressure, and partly to the mean ratio of expansion being less with the larger chamber. This result is analogous to that consequent on increasing the clearance in a gas engine.

The amount of heat imparted to the barrel of a Service 0·303 rifle by the Service charge is rather more than equivalent to the muzzle energy. The muzzle energy represents about 66 ft.-lbs. per grain of cordite, and the heating

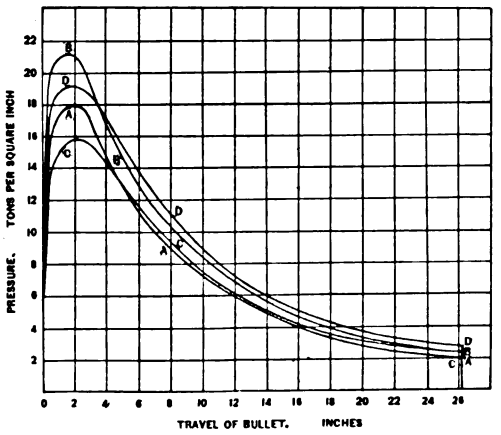

FIG. 3.—CURVES SHOWING THE EFFECT OF INCREASING THE CHAMBER VOLUME OF A CARTRIDGE.

TABLE II.—DATA REFERRING TO CURVES IN FIG. 3.

		Velocity.	Muzzle Energy.	Indicated Energy.	Mechanical Efficiency.	Pressure.
		ft./sec.	ft.-lbs.	ft.-lbs.	Per Cent.	tons sq. in
A.—30 grains 0·033 strand	Short case	2,043	1,988	2,627	75·7	17·9
B.—33 grains 0·033 strand	Short case	2,190	2,284	3,036	75·5	21·1
C.—33 grains 0·033 strand	Long case	2,058	2,017	2,567	78·5	15·8
D.—36 grains 0·033 strand	Long case	2,221	2,349	3,105	75·7	19·1

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of the barrel about 70 ft.-lbs. per grain. Some of the latter is due to the friction of the bullet in passing up the barrel, which amounts to about 25 per cent. of the indicated energy. It may be assumed that half of this is imparted to the barrel and half carried away by the bullet, so that the heat balance may be stated as follows :—

	ft.-lbs. per grain.
Carried away by bullet as kinetic energy	66
„ „ „ heat . . .	11
Imparted to barrel by friction . .	11
„ „ „ hot gases . .	59
Carried away by gases.	88
	235

The ratio of the kinetic energy of the bullet to the total energy available is therefore about 28 per cent. with the Service charge. The distribution of the losses will vary with the nature of the charge.

Fig. 4 shows the pressure curves given by various charges of flat strip cordite in the long 0·303 case; the curve A, for 30 grains in the short case, is given for the sake of comparison. It will be seen that the pressure increases rapidly with the charge. This is due (*firstly*) to the increase of burning surface, which is proportional to the charge, and (*secondly*) to the diminution of the net volume of the case owing to the greater space occupied by the larger charges.

With a 30-grain charge, the cordite in the small case occupies approximately 40 per cent. of the volume of the case, leaving about 60 per cent. to be reckoned as net volume. The 10 per cent. increase of charge in the short case will give a 10 per cent. increase of initial surface and nearly 7 per cent. reduction of net volume. The increase of initial surface with flat strip cordite is always accompanied by an increase of the critical velocity. On the other hand, with strand cordite, if the initial surface is increased by using a smaller size of strand and keeping the charge the same, it does not follow that the critical velocity is increased; the burning surface is reduced at the critical point in a greater proportion with thin than with thick strands, so that the critical velocity is much less affected by reduction of thickness with strand than with flat strip cordite. Thus, by substituting 0·023 for 0·033 strand, the pressure is increased about in proportion to the initial surface of the charge, that is to say, inversely as the diameter. With flat strip cordite, however, the rise of pressure is more nearly proportionately to the square of the initial surface when the net volume is kept constant. This is owing to the approximate constancy of surface during combustion. Comparing the pressure of a 30-grain charge in the short case with that of a 44-grain charge in the long case, we find that a 47 per cent. increase of surface results in a 92 per cent. increase of pressure, or the pressure varies nearly as the square of the surface, the net volumes being approximately the same in both cases. The greater efficiency of the cordite burnt in the small case is evident, since 30 grains in the short case give about the same velocity as 33 grains in the long case (although, of course, the pressure is somewhat higher), this being due to the higher ratio of expansion. As the charge is increased

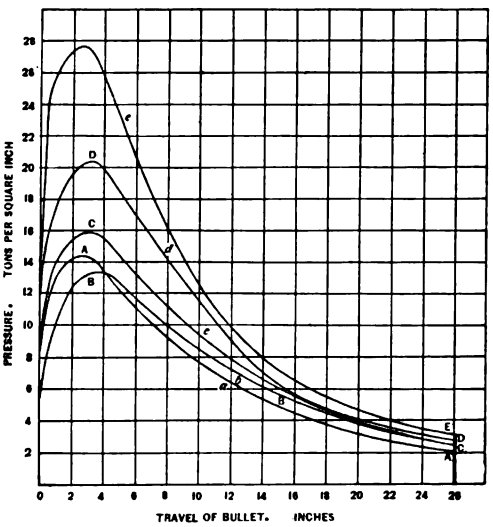

FIG. 4.—PRESSURE CURVES FOR VARIOUS CHARGES OF FLAT STRIP CORDITE IN LONG 0·303 CASE.
Cordite all burnt at points a, b, c, d, and e.

TABLE III.—DATA REFERRING TO CURVES IN FIG. 4.

	Velocity.	Muzzle Energy.	Indicated Energy.	Mechanical Efficiency.	Pressure.
	ft./sec.	ft.-lbs.	ft.-lbs.	Per Cent.	tons sq. in.
A.—30 grains 0·185 × 0·022 flat strip (short case)	2,034	1,970	2,542	77·5	14·4
B.—33 grains 0·185 × 0·022 flat strip (long case)	2,058	2,017	2,608	77·3	13·35
C.—36 grains 0·185 × 0·022 flat strip (long case)	2,223	2,357	2,974	79·3	15·8
D.—40 grains 0·185 × 0·022 flat strip (long case)	2,445	2,850	3,592	79·5	20·3
E.—44 grains 0·185 × 0·022 flat strip (long case)	2,642	3,324	4,380	76·0	27·6

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the efficiency in the long case becomes greater, as will be seen by Table III.; this is the result of more rapid burning of the cordite under the higher pressure. With the 33-grain charge the cordite is all burnt after the bullet has moved about 12½ inches; with the 36-grain charge the distance is 10 inches; with 40-grain, 7½ inches; and with 44-grain, 5 inches. These distances are calculated from the velocity of the bullet due to the area of the pressure-time diagram, which also determines the thickness of cordite burned. The point of maximum pressure occurs earlier as the charge is increased, since whilst the critical velocity is practically proportional to the charge, the pressure increases nearly as the cube of the charge; if the pressure only increased as the square of the charge, the critical point would be the same for all charges. By increasing the thickness of the cordite as the square root of the charge, and keeping the net volume of the chamber constant, the efficiency may be kept constant and the point of complete combustion the same for all charges. The velocity under these conditions would vary as the square root of the charge, and the pressure directly as the charge.

Fig. 5 shows the pressure curves for two charges in which the surface and net volumes were identical, one of them being given by 45 grains of flat strip made from cordite M.D.

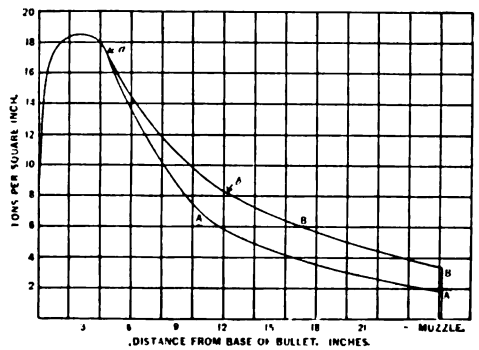

FIG. 5.—PRESSURE CURVES FOR TWO CHARGES WITH EQUAL SURFACES AND NET VOLUMES.

AA.—*Curve for* 30·6 *grains of flat strip*, 0·1 *in.* × 0·013 *in., in short case.* BB.—*Curve for* 45 *grains of flat strip* 0·1 *in.* × 0·019 *in., in long case.*

Cordite all burnt at *a* and *b*.

(or modified cordite) 0·1 inch wide and 0·019 inch thick, in the long case; whilst the other is given by 30·6 grains of a strip of similar material 0·1 inch × 0·013 inch in the short case. It will be seen that the two curves are identical until the bullet has moved about 4½ inches, at which point the thinner strip is completely consumed. From this point onwards, the pressure curve of the thin strip falls more rapidly than that of the thick strip. In the latter case the combustion is completed when the bullet has moved about 15 inches. This experiment seems to prove that it is the net volume, and not the total volume, of the case which determines the pressure, since the total volume with the longer case is 20 per cent. greater than in the short case, and yet the pressures for the equal surfaces are identical. A similar experiment shows that with equal surfaces and different net volumes the pressure is approximately inversely as the net volume.

To sum up, it appears from experiment and also from calculation that when the burning surface is approximately constant during combustion, the pressure for a given net volume is proportional to the square of the surface, and for a given surface is inversely as the net volume. Calculation further shows that for equal surfaces and net volumes the pressure is inversely as the fourth power of the bore. The calculations are made from the equations given in Part I., *viz.*:—

Critical velocity = volume of gas evolved per second ÷ area of bore,

and $\log_e (P_2/P_1) = A.t.$

The critical velocity is the velocity at the point of maximum pressure, and P_1 and P_2 are the initial and final pressures for a short interval of time t during which the net volume may be assumed to have a constant mean value, and A is a constant, the value of which is given by (*volume of gas evolved per second under the mean pressure – increase of volume of chamber per second due to velocity of bullet*) ÷ *the mean net volume of the chamber during the interval t.* It will be seen that A continually diminishes as the bullet accelerates, and at the critical velocity A = 0.

Taking 30 grains of 0·033 strand cordite in the Service cartridge, the initial surface is about 9·2 square inches. The net volume is 0·117 cubic inch. The initial value of A is therefore equal to—

9·2 × *volume of gas per square inch of surface per second ÷ net volume of chamber.*

A large number of experiments tend to show that about 95 cubic inches of gas per second are given off at 60° F. from each square inch of surface of cordite at any given pressure, so that the initial value of A for the charge we are considering is 9·2 × 95 ÷ ·117 = 7,470; that is to say, the pressure increases from 1 ton per square inch to 2·7 tons per square inch in 1/7,470 second.

(*To be continued.*)

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ON THE ELECTRIC CONDUCTIVITY OF A VACUUM.

By J. A. FLEMING, M.A., D.Sc., F.R.S.

IN the thirteenth series of his Experimental Researches on Electricity, Faraday discusses the question whether a vacuum should be considered to be a conductor or a non-conductor of electricity. The subject may seem, to some people, to be of purely academic interest and devoid of any technical value. Since, however, any increase in knowledge concerning the manner in which electricity is moved from place to place, and its relation to atoms of matter, is extremely practical, the consideration of the conductivity of a so-called vacuum is not an unimportant matter. Since the time of Faraday we have been able to make vacua far more complete than any attained by him. Nevertheless, any vacuum we can make can only be so called by courtesy. In air at ordinary pressure there are about 10^{20} molecules per cubic centimeter; hence, even if we can take out from any space all but one hundred-millionth of the original gas at atmospheric pressure, the molecular population of that space must still be very large. Sir James Dewar has shown that extremely high vacua can be most rapidly produced by condensing the residual air in an ordinary vacuum by cocoanut charcoal, cooled by liquid hydrogen, and it may be possible in this way to remove from any space all but a very small proportion of the gaseous matter present.

Let us assume that we make a high vacuum of one hundred millionth of an atmosphere in a glass vessel, and that in it are placed two metal plates, say of platinum, at a distance of a millimeter apart. Let these plates be connected to platinum wires sealed through the glass. If the plates are cold, it is then possible to create between them a difference of potential of 100,000 volts or so, and yet not cause any discharge or the slightest measurable current across the space. A vacuum can be made such that an induction coil giving a spark of several centimeters length in air will not strike across a space of one millimeter in the vacuum between cold metal terminals. This fact at first sight appears to show that a high vacuum is a very perfect non-conductor, and this opinion has generally been held.

If, however, we modify the experiment slightly, we shall be able to show that the highest vacuum we can produce may, under other conditions, be a very good conductor.

Imagine a bulb of glass, made as in Fig. 1, containing two loops of platinum wire, or better still, two carbon filaments. Let this bulb be exhausted as completely as possible, so that in it the highest attainable vacuum is made. To achieve this, the filaments must be heated to bright incandescence, whilst the exhaustion is going on. Having done this, if the secondary terminals of an induction coil are connected to the two separate filaments when

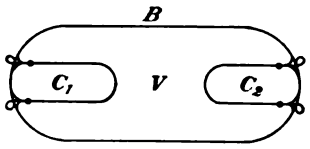

FIG. 1.

B.—Bulb containing high vacuum.
C_1, C_2.—Carbon filaments sealed in, like an incandescent lamp.

cold, no discharge will take place across the vacuum between them, thus apparently showing that the space is a very perfect non conductor. Suppose, however, that we render one or both of these filaments incandescent by passing electric currents through them by means of two insulated batteries of secondary cells, S_1, S_2 (Fig. 2), it will be found, on connecting a sensitive galvanometer G, and a single cell S, as a shunt to the two negative terminals of the two separate filaments, that a current of several milliamperes will pass across the vacuum under the electromotive force of this single cell. The arrangements should be as shown in Fig. 2. If only one of the filaments is ignited, and if it is that in connection with the negative terminal of the single cell in the shunt circuit, then the current still passes; but if the other filament alone is ignited, no current, or only a very much smaller current, passes. The same experiment can be repeated using platinum loops instead of carbon filaments, and it shows that a high vacuum may be a very good conductor, provided that the negative electrode is rendered incandescent. This shows that the obstruction which a high vacuum offers to the passage of electricity is not due to the mere reduction of the matter in the space (that is, to the rarefaction of the gas), but is, in some way or other, largely dependent upon the temperature of the electrodes; the resistance to the passage of electricity through a vacuum can be rendered very small by intensely heating the negative

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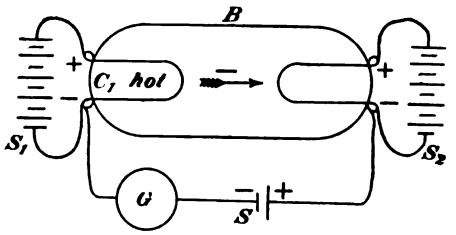

FIG. 2.

B.—Vacuum bulb.
C_1.—Carbon filament to be rendered incandescent by insulated battery S_1.
G.—Galvanometer.
S.—A single cell sending negative electricity from hot filament to the cold one.

electrode. Hence, such a bulb containing two carbon filaments forming the two electrodes, one of which can be rendered incandescent, will act as a *vacuum valve*, allowing the electricity to pass in one direction, but not in the other. It permits negative electricity to pass out of the hot electrode, but not out of the cold electrode. If, in place of a single secondary cell (arranged in the shunt circuit, as in Fig. 2, to give a direct current), we employ an alternator, giving an alternating current, but still keep the galvanometer in the circuit, we shall find, as was first shown by the writer in 1889, that a continuous current passes through the galvanometer; in other words, the vacuum possesses a unilateral conductivity, and separates out the two constituents of the alternating current, passing one but not the other. This fact was first demonstrated and described in a paper by the author of this article, presented to the Royal Society in 1889.

In this respect, such a vacuum valve resembles an aluminium-carbon rectifier. It is well known that, if a carbon or iron plate is placed, together with an aluminium plate, in some electrolyte yielding oxygen, then a current of positive electricity can pass from the carbon to the aluminium, but not in the opposite direction. This fact is the basis of some devices for rectifying alternating current, such as a Nodon valve. To return, however, to the vacuum valve. If we take measurements of the current passing through the vacuum when the negative electrode is an incandescent carbon filament and the other a cold metal plate, and, at the same time, measure the difference of potential between the electrodes, we find that the conductivity, as measured by the ratio of current to voltage, is not constant, but varies with the electromotive force. In other words, the resistance of the vacuous space does not follow Ohm's law. As the electromotive force is steadily increased, the current gradually increases up to a certain maximum, and then slightly falls again. The firm line curve in Fig. 3 shows the general relation between current and voltage up to 100 volts; and it will be noticed that the curve is something like a magnetisation curve of iron. It follows that the curve of conductivity, represented by the dotted line, is a curve rising rapidly to a maximum, and resembles to some extent the curve of permeability of iron.

For an explanation of these facts we must fall back upon the electronic hypothesis of matter and electricity. According to this view, atoms of matter are built up of electrons, which are point-charges of electricity; and an atom is considered to be made up either of a collocation of positive and negative electrons

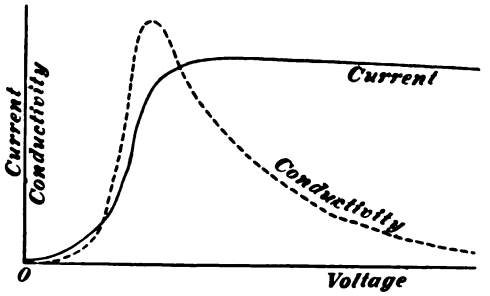

FIG. 3.—CURVE SHOWING THE VARIATION OF CURRENT AND CONDUCTIVITY THROUGH THE VACUUM VALVE, WITH INCREASING POTENTIAL DIFFERENCE BETWEEN THE ELECTRODES.

in orbital motion round one another, or else of negative electrons, or simply of electrons scattered throughout a space, which in some way or other, not yet understood, constitutes a sphere of positive electricity. In any case, facts connected with electro-chemistry and radio-activity show that atoms can break up, by giving off electrons, or can part with one or more electrons. Hence, in any mass of matter, such as a metal, there must be, in addition to the complete atoms or molecules constituting the mass, a distribution throughout it of free electrons, the percentage of these increasing with the temperature. These electrons cannot escape from the mass when cold, because if they did they would leave it positively electrified. If, on the other hand, we electrify the mass negatively to a high potential and raise it to a high temperature, electrons can escape freely from it. In every mass of matter there is what we may call a certain "electronic pressure"; hence, it follows that the resistance which a high vacuum offers

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to the passage of electricity through it is, in fact, the resistance which is offered to the ejection or drawing out of electrons from the surface of the electrodes.

In an interesting Paper in the *Philosophical Magazine* for October, 1904, Lord Kelvin sums up the position as follows:—"The labours of many experimenters during the last fifty years, and the comparatively modern atomic theory of electricity, have thoroughly confirmed the view that the space of our best modern vacua, interstellar and interplanetary space, and generally, space occupied only by the luminiferous æther, is a very perfect non-resister of electricity passing through it. Hence, we see that the insulation of electricity in a vacuum is to be explained, not by any resistance of vacant space or of æther, but by a resistance of glass or metal or other solid or liquid against the extraction of electrions* from it, or against the tearing away of electrions or fragments of its own substance."

Lord Kelvin enters into some calculations of a very interesting kind, estimating the force required to extract an electron from the negative electrode. He considers an atom to consist of a sphere of positive electricity (it may be of positive electrons distributed through a spherical space), and he calculates the force necessary to tear a negative electron out of this environment. The force required to displace the negative electron whose charge is e by a distance x from its position at the centre of an atom whose radius is r, is equal to ex/r^2 electrostatic units. Now, the charge carried by one electron is known to be $3 \cdot 4 \times 10^{-10}$ electrostatic units, and the radius of an atom is known to be of the order of 10^{-8} centimeter. Hence, the force required to make $x/r = 1/9$, or to move an electron from the centre of the atom only one-ninth part of the way to the atomic surface, is 320,000 electrostatic units, or equal to 96 million volts per centimeter; and the force required to extract the electron altogether would be equal to 384 million volts per centimeter.

This, as Lord Kelvin shows, means a strain equal to $66 \cdot 4$ tons per square centimeter, and would rupture or pull apart the strongest steel.

It seems, therefore, clearly impossible for any electrostatic force which we can create, to directly break up atoms or draw out electrons from them. On the other hand, it is a cardinal principle in the electronic theory of electricity, that the only way in which an electric current can be produced is by the movement of electrons. Since, therefore, we can produce currents of electricity in conductors by feeble electromotive forces, it follows that free electrons must exist within the metal. We picture to ourselves, therefore, a mass of metal as follows:—

It is composed of atoms, each one of which is a complex structure of electrons in motion and vibration. Owing to collisions and mutual reactions, electrons are detached from some atoms, and constitute free point-charges of negative electricity, which remain mixed up with the atoms. The remainder of the atom from which the electron is detached is therefore positively charged, and may be called a positive ion. The free electrons are continually being set free from atoms, and taken up again by others. Hence at any one moment there is a certain percentage of complete atoms and a certain corresponding percentage of free electrons and positive ions. The equilibrium is dynamic, and no doubt determined by temperature. The free electrons can move about between the atoms and comport themselves like molecules of gas in a vessel. They cannot leave the metal, because, if they did, it would be positively electrified. Hence any attempt of an electron to remove itself from the conductor is strongly resisted. On the other hand, the electrons diffuse from one place to another in the same mass, if by any reason the concentration of electrons is different at the two places.

Creating an electromotive force in a metallic mass merely means that we make a difference in concentration or density of free electrons between different places, or that the number per cubic centimeter is greater at one place than at the other. Then there is a tendency for electrons to migrate or diffuse from the place where they are most numerous to places where they are less numerous. This diffusion of electrons constitutes an electric current. Electronic movement under variation of concentration follows the same laws as the diffusion of solids in solutions. This law, moreover, when mathematically considered, leads at once to the well-known law of Ohm defining the current under various electromotive forces in a conductor.

Suppose, then, that we seal two platinum wires into the opposite ends of a glass tube, and connect these two wires to a battery, or induction coil, or transformer. These appliances are virtually *electron pumps*, and force

* Lord Kelvin uses the term *electrion* for an infinitely small point-charge or atom of negative electricity. Most other writers, following the suggestion originally made by Professor Johnstone Stoney, call these point-charges of electricity, *electrons*.

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an excess of electrons into one piece of platinum and make a deficit in the other. The one which has an excess of electrons is the negative electrode. If the pressure is great enough, electrons may be projected from the negative electrode. If, however, the electrode is surrounded by air molecules at normal air pressure, the electrons projected from the metal never attain a very high velocity.

Imagine, now, the gas molecules greatly reduced in number—in other words, the air in the bulb rarefied and a "vacuum" made.

We have three broadly marked conditions to consider. We may have the "vacuum" low or high. We may have the electrodes cold or incandescent. We may have the electronic pressure difference, or voltage between them, small or large.

Let us define these conditions more closely. The vacuum is said to be low when the original normal air pressure in it is reduced to one-thousandth of an atmosphere, or it may be only to one three-hundredth. It is said to be high when it is reduced to one hundred-millionth of an atmosphere. The electrodes are said to be cold when not in any way specially heated. They are incandescent when brought to a bright white heat by some external means. The voltage is said to be small when the difference of potential between the electrodes is only a volt or two. It is said to be large when it is some hundreds or thousands of volts.

The phenomena which take place when the "vacuum" is not very high (that is, when the residual gas pressure is only about one-thousandth of an atmosphere), and the electrodes are cold, are very complicated. In this case we have an enormous number of gaseous atoms per cubic centimeter still left, and we have all the beautiful but complex phenomena shown by an ordinary *vacuum tube*, provided the potential difference of the electrodes is made sufficiently great (that is, providing it amounts to some hundreds or thousands of volts). The study of these phenomena has given occupation to a large number of the most distinguished physicists, and it has taken them at least half a century to unravel them. When the vacuum is very high (that is, if the residual gas pressure is something less than one ten-millionth of an atmosphere) the phenomena become simplified. We then observe the well-known effects of the Crookes or Röntgen tube. The electrons in the negative electrodes are projected from it, owing to the great electric force, with very high velocities; and as their path is not sensibly disturbed by the sparsely distributed molecules of the remanent gas, we have all the phosphorescent and other remarkable effects due to the bombardment of these electrodes, and their impact against the glass walls of the vessel or objects placed in the tube. This state makes itself evident by the apple-green phosphorescence of the glass vessel.

We may have a third set of conditions. If the negative electrode is heated to a very high temperature, then even if the electric potential of this electrode is low (that is, if there is only a volt or less difference of potential between the two electrodes) we have a very considerable current of electricity passing across a very highly vacuous space.

This can only be accounted for by the fact that the incandescent carbon or metal which forms the negative electrode is emitting vast numbers of these electrons or point-changes of negative electricity. These are flung out of the heated metal by the high velocities which they attain. Just as it would be possible to impart to a projectile such a velocity as would carry it beyond the earth's attraction, so the electrons present in the metal, when its temperature is high enough, are flung out of the mass; and if that mass is kept at a high potential this torrent of negatively-charged electrons is a current of electricity.

We have in these facts an explanation of many well-known phenomena. One effect in the case of incandescent electric lamps has been much studied by the author: as it was first noticed by Mr. Edison, it is usually called the Edison effect. A plate of platinum or other metal P is attached to a platinum wire, and this last is sealed into the bulb of an incandescent lamp L. The plate is placed as shown in Fig. 4. If, then, the filament is rendered incandescent by a continuous current, and if we connect a sensitive galvanometer G between the positive terminal of the filament and the terminal of the plate, we find a current of several milliamperes passing through it. If, however, we connect the galvanometer between the negative terminal and the plate, no current flows. Again, if we render the filament incandescent by an alternating current, we can draw off a continuous current by connecting a galvanometer between the plate terminal and either of the terminals of the filament. These phenomena are susceptible of explanation by the fact that negative electricity (that is, electrons) can escape freely from the hot carbon filament, and hence move across the high vacuum and enter the positively electrified plate. The same

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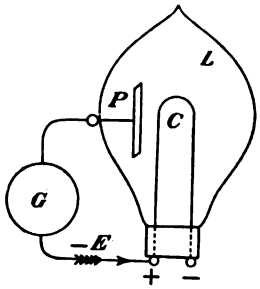

FIG. 4.

L.—An ordinary carbon filament incandescent lamp.
C.—The carbon filament, rendered incandescent by a continuous current.
P.—A metal plate, sealed through the glass.
G.—Galvanometer through which flow negative electrons from the plate P when the other terminal of the galvanometer is connected to the positive of the filament.

thing can be shown with an electric arc. The writer showed many years ago, that if a thin carbon rod (or better still, an iron tube M, closed and made chisel-shaped at one end, and cooled by water led into the interior) is placed with its sharp end just dipping into the electric arc, then a continuous current can be drawn off by a wire connecting this third pole with the positive carbon of the arc, and rendered evident on an ammeter A (*see* Fig. 5).

On the other hand, no current, or very little current, passes through a wire connecting the negative carbon and this middle pole; or, if the arc is formed with an alternating-current of electricity, in a wire which connects either carbon to a cool middle pole dipping into the arc.

These things are all consequences of the fact that incandescent carbon and metals send out vast numbers of electrons. In other words, an incandescent mass of carbon is flinging negative electricity out of itself. If it is surrounded by air at ordinary pressure the effects of this are not very marked, because the presence of vast numbers of air molecules round the metal keeps the electrons from making their way very far. They must, however, exercise an immense physical effect, and the everyday phenomenon of a coal fire and the combustion of carbon by oxygen is without doubt intimately connected with it. Let us see what account the electronic theory can give of such a familiar fact as the combustion of a piece of coal or carbon.

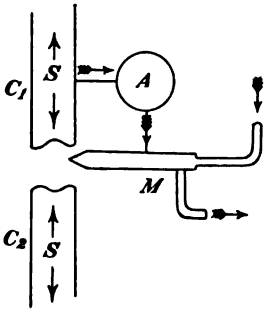

FIG. 5.—A CONTINUOUS CURRENT DRAWN OFF FROM AN ALTERNATING CURRENT ARC LAMP.

C_1, C_2.—Carbons of the alternating arc.
A. — Continuous current ammeter.
M.—Hollow iron pole kept cold by circulating water. Negative electricity flows through the ammeter from one carbon to the metal pole.

To begin the combustion, the carbon must be raised to a high temperature. As already explained, this is accompanied by a dissociation of carbon atoms. We have present in the mass of carbon not only complete carbon atoms, but free electrons or point-charges of negative electricity. Therefore there must also be the residues called "carbon positive ions," which are the result of depriving the carbon atom of one or more electrons. The carbon atom is with good reason supposed to be built up of about 12,000 electrons, and of these it can lose four negative at most. For every four free negative electrons which have escaped, or been flung out from a carbon atom, there will be left one positive carbon ion containing 12,000 or so, *less* four negative electrons. Outside the carbon there are the atoms of oxygen and nitrogen composing the air. Various atoms can, with different degrees of facility, either lose or take up additional electrons. Electro-chemical facts indicate that the oxygen atom can acquire or take up two additional negative electrons over and above the 16,000 or so which are its normal constituent number.

Hence, we may consider that, of the electrons projected from the hot carbon, some at least find their way into oxygen atoms, giving them a negative charge of electricity and converting them into negative oxygen ions.

There will, therefore, be a strong electric attraction between the positive carbon ions near the surface of the glowing carbon, which have lost four electrons, and the negative oxygen ions hard by, which have each gained two electrons. This electric attraction will be satisfied if two oxygen ions draw near to one carbon ion and form a closely united ionic group, or carbonic dioxide molecule represented by the chemical symbol CO_2. These groups being electrically neutral, remove themselves out of the sphere of action, and are the product of combustion of the carbon. As fast as the carbon ions and free electrons are removed from the glowing carbon, fresh ones are formed to keep up the number, and so the process goes on.

The temperature of the burning carbon is kept up by the conversion of potential energy of the oxygen ions and the carbon ions into atomic kinetic energy. The electrons in each ion are set in rapid vibration, and this in turn creates waves in

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the æther, which are the radiated heat and light. The process is therefore continuous and self-supporting. The combination of the carbon and oxygen ions maintains that temperature which is necessary for the continual production of the electrons in the carbon, and when it is begun at one point in the mass it speedily spreads all over it.

The nitrogen atoms take little part in the process. They do not quite so easily take up electrons as do the oxygen atoms. Hence, they are not in a condition to combine with the carbon ions.

The above process is typical, and proceeds when any metal is heated in air and oxidised or burnt. Returning, then, to the vacuum valve, the writer of this article has recently discovered, and announced to the Royal Society, an important property possessed by a high vacuum when the electrodes are at very different temperatures.

A glass bulb contains a carbon filament, such as would be used for an incandescent lamp, and is surrounded by a metal cylinder not touching the filament, the said cylinder being connected to a platinum wire sealed through the glass. Such an arrangement possesses the property that when the filament is rendered incandescent, negative electricity can pass from the hot carbon to the cold cylinder, but not in the opposite direction.

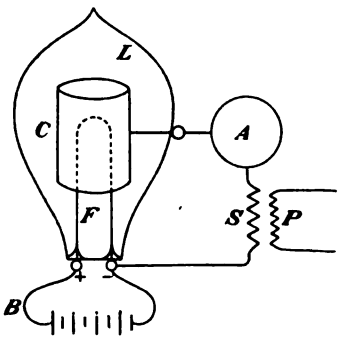

FIG. 6.—VACUUM VALVE FOR RECTIFYING ELECTRICAL OSCILLATIONS.

L.—A glass bulb highly exhausted.
F.—Carbon filament.
B.—Insulated battery.
C.—Cylinder surrounding filament.
A.—Ammeter or galvanometer.
S.—Coil in which secondary oscillations are induced by a primary coil P.

This arrangement may act as a vacuum valve if used in the following manner:—Let the filament be, for example, a 12-volt carbon filament. It must be rendered incandescent by a small insulated secondary battery B. To the negative terminal of this filament is connected one end of a circuit which includes a sensitive galvanometer A, and the other end of the same circuit is connected to the terminal of the metal cylinder C. This circuit may include the secondary coil of a small transformer or air core induction coil S, P (see Fig. 6). If, then, electric oscillations are created in the primary circuit of this transformer by the discharge of a Leyden jar or any other method, these very high frequency alternating currents produce other high frequency currents in the circuit which includes the galvanometer and the high vacuum. Only one of these sets of currents, however, can pass round the circuit, *viz.*, that which is due to a movement of negative electricity from the hot filament to the cold cylinder. The movement of electricity in the opposite direction is prevented, hence the galvanometer gives a deflection and is traversed by a continuous current. This enables us to employ a sensitive mirror galvanometer for detecting electric oscillations.

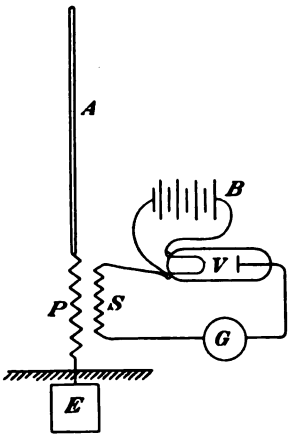

FIG. 7.—VACUUM VALVE USED AS RECEIVER IN WIRELESS TELEGRAPHY.

A.—Aerial wire.
P, S.—Oscillation transformer.
V.—Vacuum valve.
B.—Battery.
C.—*Galvanometer.*

We may modify the experiment and make use of the apparatus to show many interesting effects. We may, for instance, set up an electric oscillation by the discharge of a condenser in one circuit. This discharge produces, as is well known, a rapid alternating current dying away in intensity; the current flows first in one direction and then in the other, the interval of time between them being exceedingly small, perhaps of the order of a millionth of a second. Then at a distance several feet or several yards away, we may set up another circuit including a galvanometer and a vacuum valve, and we may produce, as above described, a deflection in the galvanometer showing it is traversed by a continuous current when we set up an alternating current in the primary circuit by

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the discharge of the condenser. We can then show that the high-frequency magnetic field which is producing this effect is entirely arrested by thin sheets of metal; for if we hold a sheet of tinfoil between the primary and secondary coils, the deflection of the galvanometer at once ceases. We can also make use of such an arrangement as a receiver for wireless telegraphy; it is not so sensitive, however, as the coherer or the magnetic detector, but is very useful for many purposes. It would then be used in the following way: Between the ærial wire A and the earth plate is inserted one circuit P, of an oscillation transformer or induction coil, the other circuit S including a vacuum valve V and galvanometer G, as already described (see Fig. 7). If, then, electric waves from a distance fall on the ærial wire, they set up in it rapid electric oscillations, and these induce other oscillations in the circuit of the vacuum valve.

If the vacuum valve has its carbon filament ignited by a small battery, it will permit only one of the constituent currents of the electric oscillation to pass, *viz.*, that for which the movement of negative electricity is from the hot carbon to the cool surrounding cylinder. Hence the galvanometer will give a steady deflection all the time the electric waves are falling on the wire, and if the galvanometer is that type of instrument called a "speaking galvanometer" (or one which responds very quickly to the rise and fall of current through it), it will give deflections larger or smaller in proportion as the wave trains falling upon the ærial are longer or shorter, and in this manner signals in accordance with the Morse alphabet may be transmitted and rendered visible by the deflections of the galvanometer.

A galvanometer of the above kind is used in submarine cable telegraphy, and we can employ precisely the same instrument by the aid of a vacuum valve in connection with wireless telegraphy.

These, then, are some of the practical problems to which we are led by the study of the electric conductivity of a vacuum.

THE PRESSURE OF LIGHT.

WHEN a body rebounds from a surface it exerts an impulsive force on the surface, owing to the reversal of its momentum. If the body possesses a mass of m grams, and its velocity normal to the surface changes from $+ v$ to $- v$ centimeters per second during the rebound, then the change of momentum is equal to $2mv$. If n bodies rebound from a square centimeter of the surface in one second, the pressure on the surface will be equal to $2nmv$ dynes per square centimeter. According to the corpuscular theory of light, a beam of light was supposed to consist of numerous particles possessing inertia, travelling with a definite velocity v. Consider a beam of one square centimeter sectional area, totally reflected normally at a plane surface; then if each particle possesses a mass m, and there are n' particles in one centimeter length (or one cubic centimeter volume) of the incident beam, the number of particles reflected per second from a square centimeter would be $n'v$, and the pressure exerted on the surface would be equal to $2n'v.mv = 2n'mv^2$. But the kinetic energy per cubic centimeter of the incident beam is equal to $n'mv^2/2$, and that of the reflected beam has an equal value; therefore, the pressure produced would be equal to twice the total kinetic energy per unit volume in the space common to the incident and reflected beams. In 1876 Dr. S. Tolver Preston derived a similar result from arguments relating to the transmission of energy by belting. Maxwell proved that the same result holds according to the electro-magnetic theory: the energy of the field is half kinetic and half potential, so that the pressure is equal to twice the energy per c.c. of the incident beam, or the total energy per c.c. in both incident and reflected beams. Lebedew, and later Nichols and Hull, have detected and measured the pressure due to light, and have found it to be in agreement with the results predicted by theory. Quite recently Professor Poynting has found that when light is transmitted obliquely into glass, there is a tangential force exerted on the surface; this is due to the fact that the direction of motion of the tubes of force is changed on passing at an angle into an optically denser medium. It has generally been supposed that elastic solid waves, and pressural waves (such as constitute sound) exert no pressure on a surface on which they fall; but Professor Poynting has found that, taking account of quantities of the second order of magnitude, which are neglected in the ordinary investigations, a pressure equal to the energy per unit volume of the wave train is also exerted in these cases.

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THE THEORY AND PRACTICE OF STEAM GENERATION.

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PART I.

By JOHN B. C. KERSHAW, F.I.C.

INTRODUCTION.

IN this series of articles the writer intends to cover, so far as limits of space will allow, the whole of the ground relating to the theory and practice of steam generation. The subject will be dealt with under the following headings:—

1. The Raw Materials.
2. The Theory of Steam Generation in Boilers.
3. The Steam-raising Plant.
4. The Chemistry of the Combustion Process.
5. The Control of the Combustion Process.
6. Test Results, and methods for attaining increased Efficiency.

A separate article will be devoted to each of these divisions, and the whole series will thus form, it is hoped, a useful contribution to the literature of the subject.

The steam-boiler plant in the past has been grossly neglected by chemists and engineers; and the result is, that in most large works and central power stations there is at present more scope for effecting economy and improvement in the boiler-house than in any other portion of the plant. Smoke prevention and fuel economy are, in fact, largely questions of scientific supervision in this department. In time, the writer believes that such supervision and attention in all large works will become general; and that not only clearer skies, but great economies in the cost of steam power will result from the changed attitude, and from the adoption of scientific in place of rule-of-thumb methods, in the control of boiler installations. Sixty years ago the pioneer in this movement for more scientific control of the use of coal for steam production—C. Wye-Williams—stated that smoke was produced and fuel was wasted because the chemistry of combustion had been neglected, not in the laboratory but in practice; and because the construction of boilers and furnaces had been too much left to those who knew little of the chemical properties of the materials consumed in them. It is sad to have to confess that this statement is practically as true to-day, as in the year 1840 when written by Williams; and that the writings and efforts of that author and his followers have produced, even in sixty years, so little change.

THE RAW MATERIALS OF STEAM GENERATION.

Fuel.—The form in which fuel may be used under steam boilers, in order to produce the heat energy which it is desired to utilise in the form of steam, is exceedingly diverse. Natural fuels are either solid or liquid, but both varieties may, by aid of suitable apparatus and plant, be converted into gaseous fuel. A natural gas which may be used as fuel is also found in certain localities in Europe and America. In the latter country it is largely used for lighting and heating purposes. At the present time there is a decided tendency to employ fuel-gas in place of solid fuel for many purposes in the arts and industries. The control of the combustion process is much more easily carried out when employing fuel-gas than when using solid fuel; and the loss of heat which occurs in the gas-producing plant is to some extent balanced by the value of the ammonia and tar products, obtained by suitable treatment of the producer-gases. Although gaseous-fuel has not been applied on any considerable scale to the firing of steam-boilers in this country, this method of steam-raising will receive increased attention and application in the future; and, in the writer's opinion, the increased use of fuel-gas is likely to provide one solution for the smoke problem which now confronts manufacturers using solid fuels for heating purposes in large cities. The use of liquid and gaseous fuels for steam-raising purposes is, however, deserving of more extended treatment than could be accorded to the subject in these articles, and therefore only solid fuels will be dealt with in this and the following articles.

Solid fuels may be classified as follows:—Wood, peat, lignite or brown coal, bituminous coal, semi-anthracite, anthracite, and coke. The first four of these are not much employed in this country for steam-raising purposes, and only the last three will be described at length in this article.

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Bituminous Coal.—This is the type of coal employed most generally on land for firing boilers, since it is much cheaper than the anthracite and semi-anthracite fuels, and when burned under scientific conditions, can be used so as to produce high efficiency and little smoke. The following are analyses * of a typical bituminous fuel from the Lancashire district; but all fuels containing over 20 per cent. of volatile matter come under this classification.

Approximate Analysis.

Volatile matter	29·10 per cent.		
Fixed carbon .	58·04	„	70·90 per cent. coke.
Ash . . .	12·86	„	
	100·00		

Elementary Analysis.

C. . . .	72·60 per cent.
H. . . .	4·79 „
O. . . .	7·28 „
S. . . .	1·64 „
N. . . .	0·71 „
Ash. . .	12·86 „
	99·88

The calculated calorific value of this fuel was in round numbers 7,000 lb.-centigrade thermal units, equivalent to 12,600 British thermal units. It is interesting to note that it contained 3·89 per cent. of H, over and above that required to combine with the 7·28 per cent. of free oxygen present in the coal; while 14·56 per cent. of the carbon was present in some form which yielded volatile hydro-carbons on heating. Although much has been written upon the subject of coal, the exact constitution and state of the various chemical elements before heating is still unknown; and it is an undecided point as to whether the O and H and volatile portions of the carbon are present in coal in the free or combined state.

Approximate analyses of other bituminous fuels, with their calculated calorific values in lb.-centigrade units, are given below:—

No.	Ash.	Volatile Matter.	Coke.	Calculated Calorific Value.
	per cent.	per cent.	per cent.	
1	12·45	27·90	72·10	7,565
2	13·80	31·00	69·00	7,347
3	6·20	33·30	66·70	8,041
4	7·75	34·00	66·00	7,764
5	6·50	36·50	63·50	7,703

* From tests made by Dr. Hethrington.

All the above tests were made on samples dried at 230° F., and the low percentages of ash contained in samples Nos. 3, 4, and 5 were due to their being washed slacks of exceptional cleanliness. When the percentage of volatile matter, yielded by a fuel on heating, rises above 35 per cent., the fuel is exceedingly difficult to burn without smoke production. The percentage of volatile matter given off by a fuel is in reality a measure of the difficulty of burning it under the boilers, with perfect combustion of its component parts. Bituminous coals containing over 36 per cent. of volatile matter are known as "*cannel*" coals, and are used chiefly for gas-making purposes. All bituminous fuels require careful management and large brick-lined combustion chambers, if they are to be burned without smoke.

Semi-Anthracite or *Steam-coals.*—Fuels which, when heated, yield from 10 per cent. to 20 per cent. of volatile matter are known as semi-anthracite or steam-coals. They are very largely used for steam-raising purposes in the Royal Navy, and by factories located in cities where smoke prosecutions are frequent. Approximate analyses of typical semi-anthracites are given below:—

No.	Ash.	Volatile Matter.	Coke.	Calculated Calorific Value.
	per cent.	per cent.	per cent.	
1	14·95	10·00	90·00	7,405
2	15·25	11·80	88·20	7,398
3	10·00	12·50	87·50	7,855
4	10·75	13·60	86·40	7,783
5	8·85	15·50	84·50	7,950

Fuels of this type can be burned without smoke production in most types of boiler-furnace, and they do not require large combustion chambers or very skilled management in order to obtain perfect combustion. As shown by the approximate analyses, the greater portion of the fuel remains as an incandescent mass of coke after the preliminary heating upon the fire-bars of the furnace, and radiation transfers the heat from this mass of glowing fuel to the water in the boiler.

Anthracite.—Anthracite is the nearest approach to coke in chemical constitution which is found naturally, but it differs from coke in its physical properties, being very dense and of shining appearance. Anthracite gives off only from 3 to 10 per cent. of volatile matter when heated, and consists chiefly of fixed carbon, with little oxygen or hydrogen.

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The following is an approximate analysis of a typical South Wales anthracite fuel :—

Ash.	Volatile matter.	Coke.	Calorific value.
1·70%	3·64%	96·36%	8,305

Anthracites are difficult to ignite, owing to their density and low percentage of volatile matter; but under proper conditions this type of fuel can be burned completely, and it yields a very intense but localised heat. Anthracite is chiefly used in metallurgical operations, and is not employed to any great extent for steam-raising purposes; but when so employed no combustion chamber is required and the boiler surface may be placed close to the mass of burning fuel.

Coke.—Coke is the porous mass which remains behind after heating any natural or artificial fuel to redness, without access of air, in a closed vessel or retort. This process is known as that of "dry-distillation." The volatile matter under these conditions is driven off, and the fixed carbon and the ash constituents of the fuel remain in the retort. The greater the percentage of volatile matter driven off, the more porous is the coke which remains in the closed vessel in which the heating has been carried out. When wood or bone is employed as raw material, the product is generally termed *charcoal*, and the term *coke* is reserved for the product obtained by the dry distillation of cannel or other bituminous fuels. The greatest proportion of coke is obtained in this country as a by-product in the manufacture of coal gas, and is known as *gas-coke;* but very large quantities are also produced for use in the iron industry, special coking plants being attached to most large blast-furnace installations.

The use of coke for steam-raising purposes is very limited, since its price is comparatively high; but it is sometimes purchased and mixed with bituminous fuel, to lessen the trouble from smoke in very heavily worked boiler plants. Coke can be burned completely without any combustion chamber.

The following is an approximate analysis of a typical coke :—

Ash.	Volatile matter.	Coke.	Calorific value.
18·85%	1·90%	98·10%	6,972.

Owing to the loss of the volatile constituents of the fuel, the percentage of ash in coke is always higher than that of the original fuel.

Origin of Fuels.—All naturally occurring solid fuels are held to be modifications of wood and woody fibre; absence of air, heat, and pressure being the agencies which bring about this decay and fossilization of the vegetable matter. Classified in order of their age, we have the following list of solid fuels :—

Wood, peat, lignite, soft or bituminous coal, hard or steam coal, and anthracite. Geologists assert that the last-named is the oldest of the natural solid fuels. Cellulose, the chief constituent of wood and woody fibre, is represented by the formula—$C_6H_{10}O_5$, and contains 44 per cent. only of carbon; while anthracite contains 90 per cent. The process of conversion of wood into coal is thus accompanied by a gradual escape of the oxygen and hydrogen, which make up 56 per cent. of the weight of cellulose, and a gradual increase in the density and hardness of the product of this change. Lignite, soft or bituminous coal, and hard or steam coal, are the successive stages in the conversion of wood into anthracite. Peat is a similar product from the plant life which grows in bogs of less age, and therefore of less fossilized character, than coal. In peat, the percentage of volatile matter which is given off on heating is often as high as 65 per cent., and the solid carbon is thus less than one-third of the total weight of the peat. Time, heat, and pressure would no doubt convert peat into a fuel resembling coal.

Petroleum and natural gas are fuels that have been produced by another series of changes in the strata of the earth's crust; but limits of space will not permit of any discussion of the various theories relating to the formation of these products.

The Testing and Valuation of Fuels for Commercial Purposes.

No raw material used in our industries is bought and sold with less attention to scientific data than coal.

The usual plan is to buy without any preliminary testing, and to imagine that all coal from the same colliery, or from the same seam, must have the same composition, ash contents and thermal value. This is a gross fallacy, and would be dispelled, for most people, by a visit to the bottom of a coal-pit. One colliery is often working two or more seams of coal of very diverse character, and the layers of shale and dirt above and below the two seams are necessarily disturbed, and brought in varying quantity with the coal to the bank. It is evident, therefore, that the coal as delivered in the waggons can have no fixed or definite value. The only safe plan for checking the supplies, therefore, is to follow the example of checking other raw materials, and to sample and test the coal as delivered, at short intervals of time. This system of checking the quality of coal sup-

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plies is now followed in many of the more scientifically-managed manufacturing industries of this and other countries, and in time, the writer believes, it will become general.

The sampling of fuel should be carried out in accordance with the rules followed for sampling other bulky materials: that is to say, a fairly large sample containing a fair proportion of lumps and smalls should be subjected to repeated crushings and quarterings, until only a few pounds remain. From a one-pound sample of this remainder, the chemist, by following the same method, can obtain a finely powdered sample of a few grams, which is truly representative of the main bulk of the fuel.

The laboratory examination of fuel should cover tests for moisture, ash, coke, fixed carbon, volatile matter, and calorific value. The methods and apparatus required for these tests will be described by the present writer later, in a special article dealing with "Fuel Testing for Technical Purposes." From the results of this approximate analysis, the calorific value can be calculated by means of a formula—worked out by a French chemist named Goutal. This formula is as follows:—

$$P = 82C + aV.$$

Here P is the calorific value, C the percentage of fixed carbon, V the percentage of volatile matter, and a a variable co-efficient, depending on the amount of ash and water in the fuel. Using the formula—

$$V^1 = \frac{V \times 100}{C + V}$$

the following values are obtained for (a):—

V^1 =	5	10	15	20	25	30	35	38	40
(a) =	145	130	117	109	103	98	94	85	80

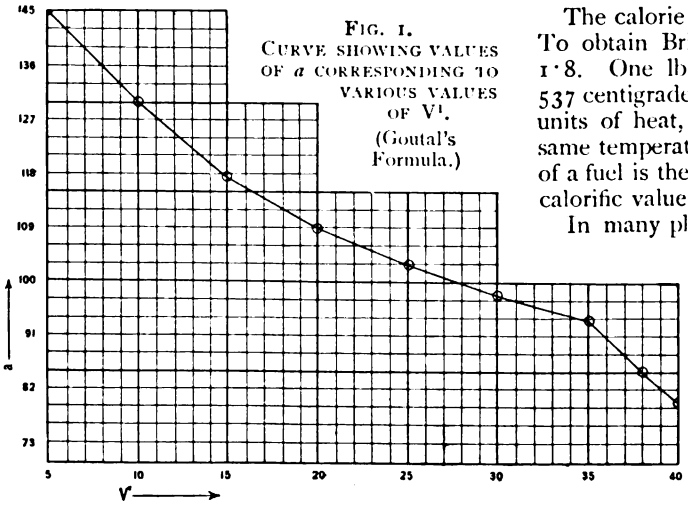

FIG. 1.
CURVE SHOWING VALUES OF a CORRESPONDING TO VARIOUS VALUES OF V^1.
(Goutal's Formula.)

and if these figures be presented in graphic form, we obtain the diagram reproduced in Fig. 1.

The calorific values of a very large number of fuel samples have been calculated by the writer by aid of this formula, and have been compared with the values obtained by direct tests—and in most cases the agreement has been close, and the margin of difference within 2½ per cent.

Since the prices of different coals vary within very wide limits, and the calorific values also differ greatly, it is not at first sight easy to determine which is really the better coal for the money. The following method of comparison may then be applied, in order to enable a correct judgment to be arrived at. The prices of different coals *delivered in the bunkers at the works* are expressed in pence per ton, and this figure is then divided into the thermal units—obtained either by calculation or by direct test—for that particular fuel. The result is the calories purchasable per penny of outlay. Provided that correct conditions of stoking and draft are used in burning the fuel under the boilers, that coal will prove the most economical which comes out highest in this comparison.

That wide variations exist in the value of coals when judged by this method, is proved by the following list of six typical coals, with the calories purchasable for one penny of outlay:—

South Wales Hard Coals
- No. 1.—Calories per 1*d*...30·6
- No. 2.—Calories per 1*d*...40·0
- No. 3.—Calories per 1*d*...57·2

Lancashire Soft Coals
- No. 1.—Calories per 1*d*...53·2
- No. 2.—Calories per 1*d*...66·3
- No. 3.—Calories per 1*d*...86·2

The calorie used is the lb.-centigrade unit. To obtain British thermal units, multiply by 1·8. One lb. of water at 212° F. requires 537 centigrade units, or 965·7 British thermal units of heat, to convert it into steam at the same temperature; and the evaporative power of a fuel is therefore obtained by dividing the calorific value by one of these numbers.

In many places, actual steam-raising trials are made when placing fuel contracts; and the choice of fuel is more often decided by the results of these, than by consideration of the laboratory test results.

In the writer's opinion, the discrepancies which often occur between the two methods of judging the value of a fuel

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are due to the fact that each coal requires special conditions of air supply, grate length, firebars, etc., in order to obtain the highest efficiency when burning it; *and this adaptation of the furnace conditions to each particular coal is seldom made.* The practical steam-raising trials *as at present carried out*, are therefore not an exact test; and the laboratory test is to be preferred, as much less expensive and troublesome to carry out, and more scientifically exact in its results.

The increasing attention which is now being given to the calorimetry of fuel is, however, tending to increase confidence in the results obtained. In time, the writer has little doubt that large fuel contracts will be based on the results of laboratory tests; instances have already come under his notice in which coal has been sold on such a basis of valuation.

Water.—The water intended for use in boilers for steam-raising purposes cannot be too pure. The popular idea that rain-water or condenser water is too pure for use in boilers is fallacious, for their corrosive action is due, not to their purity, but to the dissolved gases present in these waters. These gases escape on heating, and pitting or corrosion is often found around the feed-pipe of boilers fed with such "pure" waters. The oxygen, carbonic acid, and other dissolved gases, which cause the pittings and corrosion, are in reality impurities of the water. In most cases, heating the feed-water to 212° F. before it enters the boiler is sufficient to remove them. In cases where pre-heating is impossible, treatment with caustic lime is generally sufficient to minimise the evil.

But water containing only gaseous impurities is not often available for steam-raising purposes; and the waters used for feeding boilers most usually contain calcium carbonate and sulphate, and the corresponding magnesium salts in solution as impurities.

The total amount of solid matter dissolved in natural waters varies from a few parts per 100,000 in good waters, up to several hundred parts in bad waters. The water supply of Liverpool, which is drawn chiefly from Lake Vyrnwy, in North Wales, contains only 6·8 parts per 100,000; but this water is of exceptional purity. All surface waters are, when free from sediment, purer than well waters. Water pumped from artesian wells sunk through the chalk strata of the earth's crust is, as a rule, most highly charged with lime salts, and is often too impure to be employed in boilers without some preliminary treatment with chemicals, to remove portions of these impurities. The clearness of a natural water is no guide to its suitability as a boiler feed-water, and only chemical tests can be relied on to decide this point. All waters containing over twenty parts of solid matter per 100,000 of water, either dissolved or as a sediment, should receive chemical treatment before use for steam-raising purposes. On boiling, these waters deposit their lime salts as an incrustation on the boiler plates, and such incrustations are always the thickest and hardest, and therefore the most dangerous, at those points in the boiler where the heat transmission is the highest, and risk from overheating of the plates the greatest. In Lancashire boilers this point is the crown of the arch of the fire-box; and when collapse of such a boiler from scale occurs, it is usually at this point.

The lime salts found in natural waters are the carbonate and the sulphate. The former can be removed by two methods. The carbonate of lime is held in solution by the aid of an additional molecule of carbonic acid, and since this escapes on boiling the water, no addition of chemicals is required to precipitate this salt. Mere heating of the water to 220°F., and *keeping it at that temperature for some time*, causes all the lime carbonate to fall out as a flocculent white precipitate. Several well-known feed-water heaters and detartarisers are based on this principle.

The other method of removing the calcium carbonate is to add caustic lime to the water. This combines with the additional molecule of carbon dioxide, and forms calcium carbonate, which carries down with it the original calcium carbonate contained in solution in the water. The reaction takes place in the cold, but the precipitate separates better from hot solutions.

Calcium sulphate is more difficult to remove from natural waters, and since it forms a very hard and compact scale, it is much the more objectionable impurity.

It is decomposed by treatment with sodium carbonate, however; sodium sulphate and calcium carbonate being formed. The former is an easily-soluble salt, and does not separate in the boiler; the latter separates as a flocculent precipitate, as before. This reaction occurs most quickly and completely when the feed-water is heated.

The reactions with the magnesium salts follow on the same lines, so that all the commonly occurring dissolved impurities of natural waters can be removed by treatment with caustic lime and carbonate of soda.

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All the well-known patented forms of water-softening apparatus are based on these chemical reactions. They differ one from the other, simply in the mechanical arrangement of the plant, and in the devices used for rendering the apparatus automatic in its action. The best recent description of water-softening apparatus will be found in a paper read by Stromeyer and Baron before the Institution of Mechanical Engineers in December, 1903. This paper was printed in full in most of the technical journals of that date, and readers desiring further information on this subject are referred to it.

The use of secret compositions for putting into boilers, in order to prevent scale and grease troubles, is not to be recommended. The impurities of a boiler-feed water should be separated as far as possible *outside* the boiler. The addition of caustic soda to the water as it enters the boiler is also another practice which is to be condemned, excepting under expert chemical advice, for under certain conditions it does more harm than good, and increases the tendency of the boiler to prime.

When added to a natural water containing both calcium carbonate and calcium sulphate as dissolved salts in certain proportions, caustic soda may remove both impurities; for it first takes up the surplus molecule of carbonic acid, and forms carbonate of soda, with precipitation of the naturally-formed calcium carbonate, and then reacts with the sulphate to produce another molecule of calcium carbonate. It is evident, however, that this reaction can only be complete when the relative quantities of these impurities are present in the proportions represented by the following equation :—

$$CaCO_3 + CO_2 + CaSO_4 + 2NaOH = 2CaCO_3 + Na_2SO_4 + H_2O,$$

and this will not often occur in actual work.

Oil and grease are sometimes present in water used for boiler-feeds. When present, great care and attention should be given to their removal, for a large number of boiler explosions have been traced to greasy deposits within the boiler.

When water from surface and jet condensers is employed as make-up for the boiler feed water, this danger is of course greatly increased.

Sand filters and grease separators are employed in many works to remove oil and grease from the condenser water: but some authorities (including Stromeyer) state that these are not absolutely effective, and that chemical treatment is necessary to remove the last traces of oil and grease from the water. This can be most cheaply effected by first passing the condenser water through a sand filter or filters, and then adding it to the ordinary boiler feed supply, and passing it through the softening plant or apparatus. The calcium carbonate precipitated in this will then carry down all the remaining oily and greasy particles.

Testing Natural Waters. — A trained chemist is required for carrying out this work efficiently, but a few notes on the subject of feed-water testing will be given here.

The dissolved impurities of water are usually expressed in English or "Clark" degrees of hardness—one degree of hardness being represented by one grain of calcium carbonate in a gallon of water. This is equivalent to one part of calcium carbonate in 70,000 parts of water, since 70,000 grains are contained in one gallon. The hardness due to calcium carbonate is known as temporary hardness, and that due to calcium sulphate is known as permanent hardness. The former, as we have seen, can be removed by boiling. The method of estimating the hardness of a water generally employed is that known as "Clark's" test, and depends upon the use of a standard soap solution, which is run into a measured volume of the water until a permanent lather is obtained. If then the total hardness of a water be first determined by this test, and then the hardness of the same water after boiling, one obtains figures from which the amount of calcium carbonate and calcium sulphate present in the water can be calculated.

The soap method of determining the amount of these salts in waters has recently given place to methods which depend less upon the individuality and practice of the operator; but the space available for this article will not allow the writer to deal with these at length. The method of expressing results of water analyses as degrees of temporary or permanent hardness, is also giving place to the more scientific one of stating the results as parts of calcium carbonate or calcium sulphate in 100,000 parts of water. To convert English degrees of hardness into parts per 100,000, it is necessary to multiply by $\frac{10}{7}$ or by 1·43.

The presence of oil or grease in water can be detected by shaking the sample of water with ether, in a stoppered bottle, and by evaporating the ethereal solution to dryness over a water bath. If any oil or grease be

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present in the water, it will remain behind in the porcelain basin after the ether is evaporated. The presence of oily and fatty matters in scales can be detected by heating them to redness on a platinum spatula, or in a platinum crucible. If charring occurs, or a disagreeable odour is noticed, some organic fatty compounds are probably present. Fats and oils of vegetable origin are more dangerous lubricants for engine use than the hydrocarbon oils of the paraffin class, since the former contain oxygen, and yield acids when decomposed at high temperatures in the boilers.

Chemical knowledge of a specialised kind is, however, required to distinguish between the two varieties of oil.

Air.—Although it is not generally recognised as a very important factor of the steam-raising process, the purity, dryness, and temperature of the air supplied to the boilers is almost as important as the quality of the fuel or the purity of the feed-water supply.

Ordinary coal requires, theoretically, about 12 lbs. of air for its perfect combustion, and in practice from 18 lbs. to six times this amount of air is passed through the boilers for every pound of fuel burnt. Moisture in air is not an economical constituent, and its presence does not, as popularly supposed, aid or represent any real gain in the combustion process. It is true that it is decomposed into its constituent gases, hydrogen and oxygen, by the incandescent coke lying on the bars of the furnace, and both these gases combine again to form aqueous vapour before the gases leave the boiler flues. But the thermal energy produced by this combustion is balanced by that absorbed in the preliminary separation of these two elements, and the aqueous vapour finally produced passes away to the chimney at a much higher temperature than when it entered the boiler furnace. The result is therefore a net loss of heat, and this loss increases with the amount of moisture or steam passed into the furnaces with the air required for combustion.

The air, therefore, ought to be utilised in a state as dry as possible, and the frequent escapes of steam into ash-pits and fire-boxes, noticeable in most boiler plants, and the practice of quenching hot ashes under the fire-doors, ought to be stopped, so far as possible. The importance of this question of using *dry* air for industrial operations has recently been proved by large scale experiments in America, with a blast-furnace plant, in which it was found that the consumption of coke was diminished, and output of iron was greatly increased, by passing all the air required through a refrigerating plant, and thus freezing out nearly all the moisture it contained.

The question of pre-heating the primary and secondary air supplies for boiler-furnaces will be dealt with in Article IV. of this series; it need only be pointed out here that since, on the average, 20 lbs. of air are required for every 1 lb. of fuel burnt, and since the whole of this has to be raised to the temperature of the furnace, the question of pre-heating is of some considerable importance.

The specific heat of dry air at constant pressure is 0·237 (water 1·000), and therefore to raise 20 lbs. of air through 2,500° F. will require $20 \times 2{,}500 \times 0{\cdot}237 = 11{,}850$ British thermal units. With air already heated to, say, 400° F. by the exit gases, the British thermal units required would be $20 \times 2{,}100 \times 0{\cdot}237 = 9{,}954$, or nearly 2,000 less. The saving in fuel that can be effected by pre-heating the air supply is therefore striking, and the subject is well worth serious attention on the part of boiler engineers.

(To be continued.)

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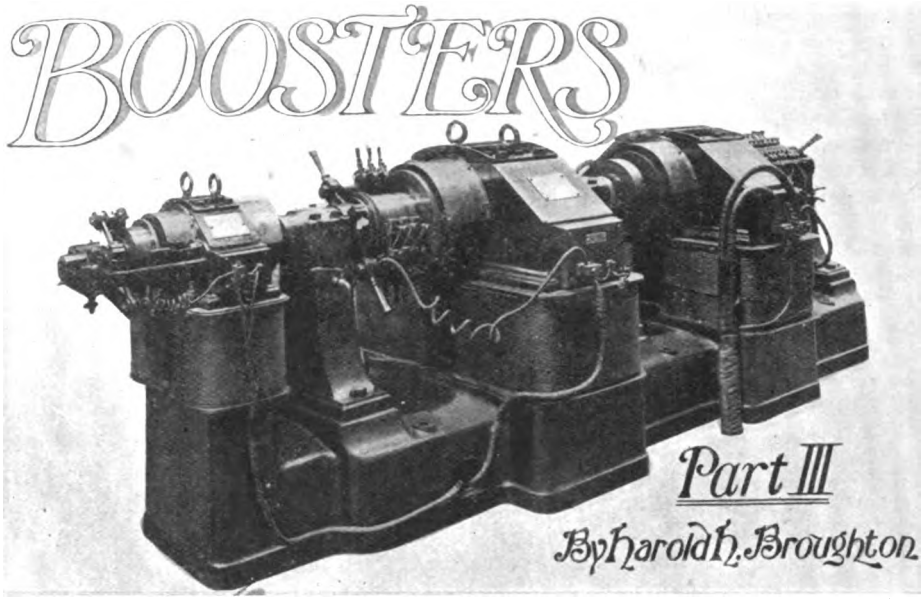
BOOSTERS



Part III

By Harold H. Broughton

THE standard design of a two-wire traction booster is shown above, and the booster panels for two- and three-wire systems are shown in Figs. 21 and 22.

The specification for a traction booster designed to work in conjunction with a 500-kilowatt set, with an 80-car load recently built by the Chloride Company, may be of interest.

The combination is to consist of three multipolar machines rigidly coupled together in line, and mounted on massive bedplate carrying four self-oiling bearings and arranged for continuous running.

Booster.—To be capable of a normal continuous output of 500 amperes, 750 amperes for half an hour, and 1,000 amperes for three minutes. Armature to be slot-wound, winding being of the drum type. Conductors properly subdivided for the elimination of eddy currents, readily removed, singly and positively driven. Core to be finely laminated, each sheet being thinly insulated and keyed to a shaft of great rigidity. Armature connections to be proof against rupture through vibration or other causes. Commutator to be extra long sections of the best hard-drawn copper, insulated with pure Indian mica of selected quality, equally aligned, and spaced circumferentially. The mica and copper to be of such proportions as will ensure equal wear. Commutator to be of sufficient depth to allow 1 inch being turned off its diameter.

The field windings to consist of one shunt coil separately excited by the small generator termed the exciter, and capable of giving a maximum boost on charge of 120 volts. A series field excited off the line and carrying a current of 100 amperes and capable of giving a maximum boost of 25 volts in the discharge direction. In addition a suitable series coil in the armature circuit capable of giving three to four volts with a current of 100 amperes passing. This coil is to account for armature reaction when a heavy current is flowing through the booster armature with no field.

Motor.—The motor to be generally of similar construction to the booster, and capable of driving the set under all conditions of load at approximately constant speed. To be slot wound and suitable for working at a pressure of 500–550 volts.

Exciter.—The exciter to be of similar construction to the booster and motor, and designed to allow the proper exciting current to flow round the booster shunt field. To be shunt-wound and to have practically no drop in terminal pressure from no load to full load. To be suitably designed for working at any fixed pressure between 500–550 volts.

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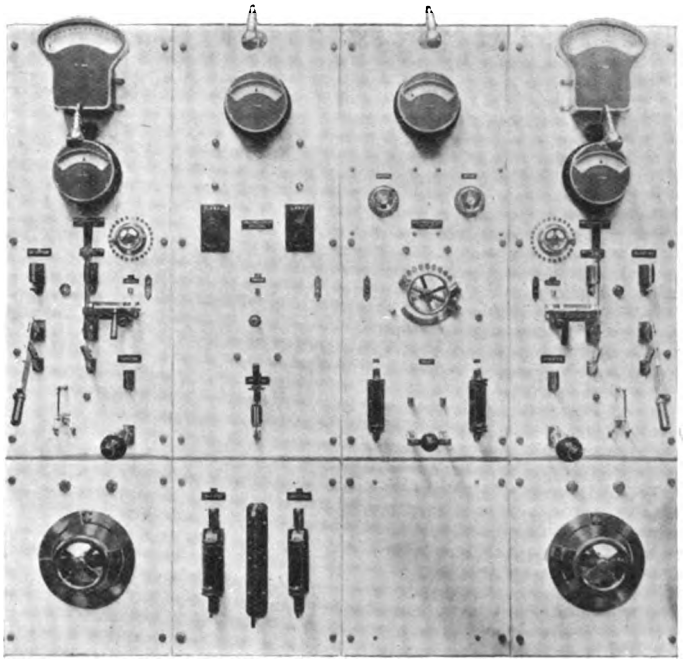

FIG. 21.—BOOSTER PANEL, TWO-WIRE SYSTEM.

Temperature.—The whole apparatus to be capable of running for six hours continuously at full normal load (500 amperes, 60 volts), without the temperature of any accessible part rising above 70°F. above the surrounding atmosphere.

Speed.—The speed of the set to be approximately 550 revolutions per minute.

Insulation.—At the end of the temperature run a pressure test of not less than 2,000 volts (alternating) to be applied to each winding.

Bedplate.—The three machines to be mounted on one bedplate, cast in pieces and bolted together. Casting to be of massive section, strongly ribbed, planed on both upper and lower surfaces, and cored out to receive magnets.

Brushes.—Brushes to be of the best carbon of ample surface and low current density, fixed in strong frame and pressed against the face of the commutator by means of an adjustable spring. Each brush may be lifted separately by means of a small insulated knob.

General.—Construction throughout to be on the most liberal lines, the scheme of insulation to be ample, mica being used whenever possible, supplemented by fibrous materials of the best quality. Field winding mounted on substantial formers or ferrules which are readily removable. Terminals and connections to be massive, and where necessary, thoroughly protected. Motor and exciter magnets to be divided, so as to permit of their armatures being lifted straight up. Booster magnets finely laminated to eliminate any lag in reversing.

Working.—The combination will generally work in parallel with one or more generators on a fluctuating load varying from 400 to 2100 amperes. The booster will so govern the battery as to charge same when the line load is less than the engine output,

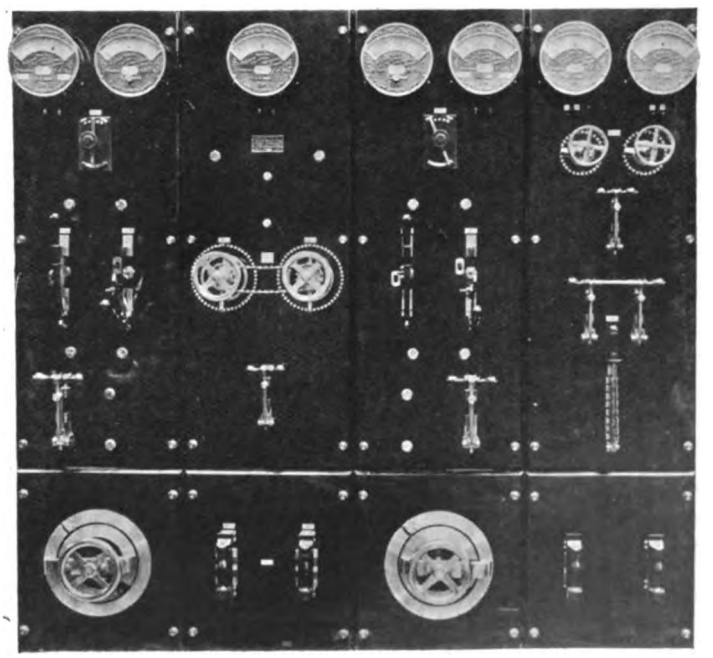

FIG. 22.—BOOSTER PANEL, THREE-WIRE SYSTEM.

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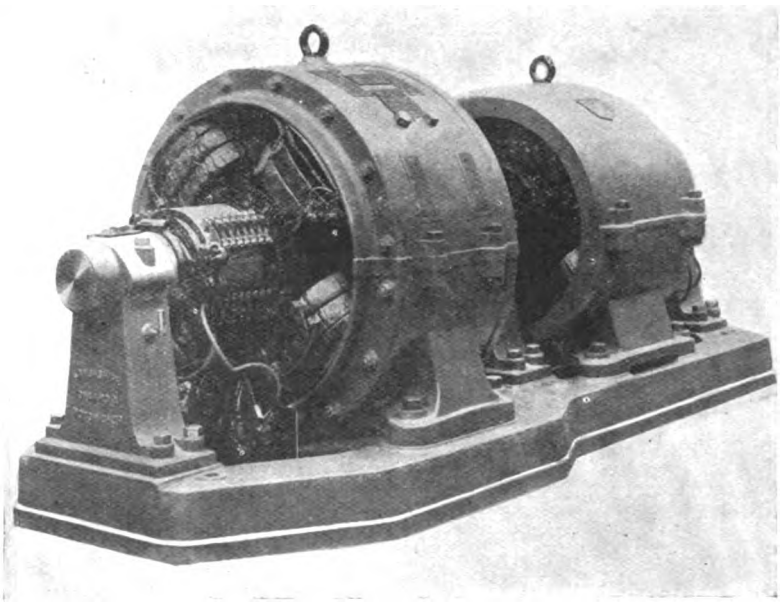

FIG. 23.—REVERSIBLE BOOSTER (LANCASHIRE DYNAMO AND MOTOR CO.).

and discharge when the load is greater than same.

The amount of charge and discharge will be exactly proportional to the difference between the engine output and the line load, so that as long as the variations are within the capacity of the booster and battery, the load on the engine will remain constant. No hand regulation is required on this machine when it has been set.

If the machine is set so that the battery will charge a little more than discharge, the charging pressure will automatically rise as the charge proceeds. The booster will also work the battery alone on the line and account for the drooping characteristic of the latter's curve.

The Lancashire Automatic Reversible Booster.—Before describing this booster, it will be of interest to hear what one of the patentees has to say on the question of having a battery and automatic reversible booster for use on a traction load. As is well known, the subject is one which Mr. Turnbull has made peculiarly his own; the writer has to thank Mr. Turnbull for permission to publish the following notes from his admirable paper on Batteries with Reversible Boosters.*

"The idea has gained currency that a booster should be designed to keep the load on the generators always at a steady value. The problem is stated thus, omitting losses in battery and booster for simplicity: The output is 2000 units per day of 20 hours. Thus a generator of 100 kw. output with a battery and booster will just answer the purpose. If the maximum load be 200 kw., then the battery should be able to give 100 kw. easily for a short time, so as to meet the peak with the aid of the generator.

"In some cases when the output is fairly regular from day to day, and where the maximum demands keep within limits, this solution of the problem is quite good, and a very efficient and good working plant is obtained by adding a battery and booster to the generator. In many cases, however, this solution is of no use at all. The output varies from day to day. Likewise a large part of the day is slack, with a heavy output during certain hours only. If, in addition to this, we have heavy and irregular peaks at all times, then it is evident we must solve the problems in quite a different manner. Take, for instance, a case where there is a plant of 200 kw. already installed; the output varies from 1500 to 2500 units per day of 20 hours, and the maximum demand is 400 kw. If we put a battery in with an output of 200 kw. for a short time, its maximum power added to the generator's maximum will give the required maximum demanded for the feeders. But if we attempt to run the generator at constant

* Read before the Newcastle section of the Institute of Electrical Engineers, in December, 1904.

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full load all the time, it will turn out 4000 units per day, and this will provide a large surplus at all times for boiling up the battery. The difficulty can be met by putting the machine to do only half-load, but in this case the combination does not give out the 400 kw. needed to meet the heavy peaks which come on at intervals. Taking everything into consideration, then, it will be found that constant load on the generators can only be got in cases where the load is similar every day, and where the size of the generator can be fixed so as to put out the proper amount of current every day at about full load. Of course, in many cases, a good deal can be done by varying the number of hours that the generator is run, so as to provide just the number of units required to meet the load, and to keep the battery properly charged."

Mr. Turnbull says that for a general solution of the problem the booster used should fulfil the following requirements :—

1. When required, it should work so as to keep the load on the generator approximately steady. This will be needed when the demand for current is approximately equal to the output of the generator. In this case, however, when a very heavy demand is made on the feeders, both generator and battery current should rise to meet it, so that the utmost power of the combination will be available. If this be not arranged, it will be often found that a heavy load will blow, first one circuit breaker and then the other, although the combined maximum power of the generator and battery would have been sufficient to meet the demand, had the booster been arranged to allow the generator output to increase along with the battery's output.

2. It should be possible to vary the apportionment of the load between the battery and generator. In a slack time the battery should do very little; also, if the traction peak should correspond with the lighting peak, then it may be desirable to let the battery take an extra load to relieve the boilers for the time being.

3. On a slack day with occasional peaks, the battery and booster combination should be arranged to respond to the peaks only, and otherwise do practically nothing, so as not to overcharge the battery. Sometimes the booster may be cut out altogether, and the battery may then with advantage be used to float on the line to meet any occasional rush of current.

4. For periods of very light load, the booster and battery should be arranged to go on to the 'bus-bars without any generator. In this case the booster should be arranged to compound up to counteract the drop of volts in the battery.

In the Lancashire Automatic Reversible Booster provision has been made with considerable ingenuity for almost every possible contingency. In external appearance it is merely a four-pole dynamo coupled to a four-pole motor; but while the motor is nothing more than a shunt motor, the booster itself has four field windings. One of these is a shunt winding across the booster terminals, excited by the difference of potential between

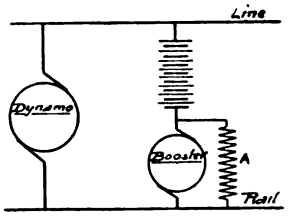

FIG. 24.—BOOSTER ARRANGED SO THAT ITS VOLTAGE, ADDED TO THAT OF THE CELLS, IS ALWAYS EQUAL TO THE 'BUS BAR VOLTAGE.

the battery and the 'bus bars. An auxiliary shunt winding, known as the "potentiometer shunt" is connected straight across the 'bus bars. A series coil is connected between the negative dynamo terminal and the negative main, and a series coil of a few turns is in series with the armature of the booster itself. Taking into account the large variations in the voltage of a battery (not only with varying current, but with the same current at different times), it is evident that the first requisite is an exciting coil which shall at all times make the

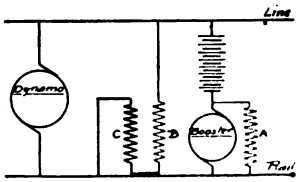

FIG. 25.—BOOSTER WITH SHUNT COIL B ACROSS 'BUS BARS, AND COIL S IN SERIES WITH DYNAMO.

sum of the battery and booster voltages practically equal to the 'bus bar voltage. This is accomplished by putting on a coil A, (Fig. 24), excited by the difference between the battery and 'bus bar voltages. If the booster is worked on the straight part of the characteristic it will be seen that this coil can be made to give a voltage on the booster armature always equal to the difference between the battery and dynamo voltage; also a very slight increase or decrease in the

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excitation will cause the battery to charge or discharge. For instance, a shunt coil B (Fig. 25) across the 'bus bars would increase the voltage on the booster, which again would increase the strength of coil A, and the battery would heavily charge; if, however, coil B is opposed by a series coil in the dynamo circuit C, the arrangement would be stable when the current in C is such that its magnetising effect just balances that of coil B; and as B is a constant shunt coil, the current in C must always be constant, as required. A few series turns are usually added in the battery or feeder circuit, to make up for the armature reaction and the C R drop of the booster itself. To take the case of the booster of a traction system: if the dynamo tries to take an overload, the coil C will overpower B, and the battery discharges until equilibrium is restored; on the other hand, if the dynamo current tries to reduce on light load, coil B overpowers C, and the battery charges until they are balanced.

As this booster depends for its control on the dynamo current, and not on any balancing of voltage depending on the dynamo characteristic, compound machines can be used as well as shunt, and all trouble from hunting and kindred causes is avoided. Most boosters which do not depend on the falling characteristic of a shunt dynamo, rely on the drop in volts on the battery and booster in discharging, which is balanced by a series coil in the feeder, and if this coil is not exactly of the right strength, the battery discharges too much or too little, usually varying with the state of the battery. The particularly valuable property of a coil in the dynamo circuit consists in the fact that it can be made as strong as desired, and always balanced by a regulator on the shunt coil to fix the dynamo current at anything required; if the current should vary, the coil acts with very great force to bring it back to the normal again, thus making the booster very stable, and greatly facilitating paralleling of the generators.

If it is desired to use the battery and the booster on the line, without the generators, coil A is disconnected, and coil C connected

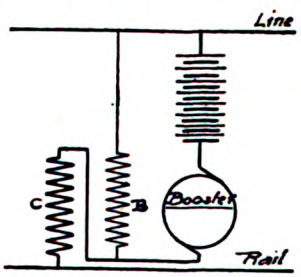

FIG. 26.—BOOSTER AND BATTERY ARRANGED TO WORK WITHOUT GENERATOR.

to help coil B, giving the battery a constant voltage with varying load (Fig. 26).

One of these boosters has been installed in the Derby station.* The machine runs normally at 800 r.p.m., and is designed for a normal working current of 200 amperes, or 300 amperes for one hour, and to supply 70 volts for prolonged periods, and 120 volts as a maximum. The machine is provided with a panel on the main switchboard. On

* For a detailed description see the *Electrician*, June 10th, 1904, p. 303.

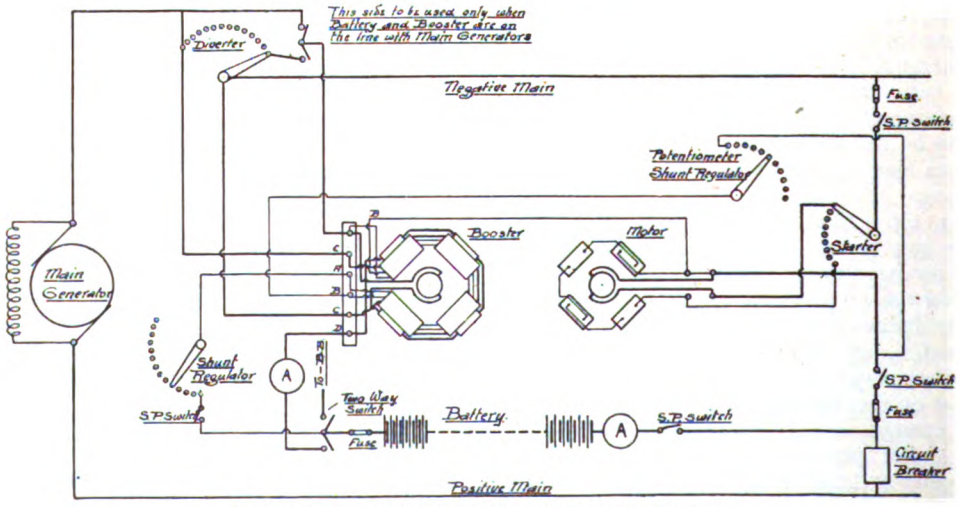

FIG. 27.—WIRING DIAGRAM FOR BOOSTER SYSTEM.

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this panel is fixed one rheostat with a 20-way switch for shunt coil A, and another rheostat with a 30-way switch in series with the "potentiometer shunt" B. Below these comes the ordinary motor-starting switch, and at the bottom of the panel a rheostat, which shunts a portion of the current in series-winding C. This latter is regulated once for all, as also the shunt-winding A, the ordinary regulation being by the 30-way switch in the "potentiometer shunt" circuit. Fig. 25 is taken from a photograph, and Fig. 29 is an actual wiring diagram of the system. In connection with the Derby station, there are two identical batteries, one for lighting, the other for traction. Each consists of 240 cells of the chloride "R" type, in lead-lined wood boxes, and each contains 29 plates, the positives measuring $9\frac{1}{4}$ in. × $10\frac{5}{8}$ in., and the negatives $9\frac{1}{4}$ in. × $10\frac{7}{8}$ in. The capacity of each battery is 675 ampere hours at a 6-hour discharge rate, and 350 ampere hours at a 1-hour discharge rate. The battery house is in two storeys, one containing the lighting, and the other the traction battery, but as the two are alike, they are interchangeable. If regulating cells had been required, it would of course have been impossible to place the battery house at a distance from the switchboard, on account of the length of connecting cable required; owing to the use of the reversible booster, however, only two cables are required to each battery.

(*To be continued.*)

SPECIAL DEVICES USED IN WEAVING.

Part VI.—Mechanical Knotters for Piecing Textile Threads.

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By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

EXCEPTING such operations as milling or fulling, dyeing, bleaching, printing, calendering or other form of finishing, through one or more of which some fabrics are required to pass before being retailed to consumers, that of *weaving* terminates a series of operations involved in the manufacture of textile fabrics. The operations may be more or less numerous, and of different kinds, chiefly according to the particular class of fabrics being manufactured. Whatever may be their character, it cannot be too strongly impressed upon all engaged in producing them, that the quality of cloth produced by a weaver is in a very large measure dependent upon the care and attention devoted to the preparation of yarn at every stage of its manufacture, from the very first treatment of the raw material, to the operation of beaming or winding yarn on to a weaver's beam; and that it is their bounden duty to prevent and remove, as far as practicable, all defects in yarn that may impede the production of good cloth, which is the ultimate object of their labour. It is impossible for the most perfect loom, in the hands of the most skilful weaver, to produce good cloth from faulty yarn, or even from good yarn that may have been carelessly prepared. Many imperfections in the yarn itself, as well as its faulty preparation, are directly due to carelessness on the part of operatives or to insufficient technical knowledge of their work and its co-relation with subsequent operations, and are irremediable by a weaver. Of the numerous causes of hindrance to a weaver and of imperfections in cloth, not the least is due to knots badly tied when piecing the ends of two threads together, either in repairing a broken thread, or in obtaining one of greater length.

During certain operations involved in the production of some classes of yarn (as doubling-winding, doubling, twining, and gassing) and also during the preliminary stages of cloth manufacture by which yarn is prepared for the final operation of weaving (as reeling, winding, warping, sizing, beaming, bleaching, and dyeing) threads are liable to break from various causes, when they require to be pieced or reunited to form continuous threads. Breakages of yarn are more liable to occur during those operations in which threads are subjected to individual tension, than when they are subjected to tension *en masse* as during any system of sizing, or beaming. But whenever a breakage occurs,

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and from whatever cause, a severed thread may only be reunited by means of a knot.

Another method of attaching the extremities of two threads is by means of a peculiar twist being imparted to them to effect a junction; but that course is only practicable and adopted in the operation termed "twisting" or "looming," whereby the threads of a new warp are separately attached to those of a previous warp, whilst the latter is already contained in the shedding harness of a loom.

Knots in yarn, due to piecings, may originate from one of two chief causes; namely, one which may be termed "accidental," resulting in breakages, and one which is "incidental," owing to the limitation of length of threads. The accidental causes are very numerous, and to a great extent preventable. They chiefly consist of thin and weak places in yarn, "slubbings" (*i.e.*, thick soft places caused by a mass of unattenuated fibres), "snarls" or curls, and broken husks of cotton seed, all of which imperfections, and many others, originate during the various stages of spinning, but generally pass undetected until the yarn is wound upon warpers' bobbins, or formed into spools or cheeses, when they cause breakages. Knots due to incidental causes are probably not nearly so numerous as the former, and they are inevitable, by reason of the limitation to the dimensions of cops, bobbins, hanks, or other forms into which yarn is converted, and the consequent necessity of joining the end of one thread to the beginning of the next, to form a continuous thread.

The presence of carelessly or imperfectly tied knots in warp yarn is one of the most fruitful sources of hindrance to a weaver, who suffers all the inconveniences which they incur, as loss of production with its accompanying loss of wages, and the usual penalties of producing inferior cloth. Long-tailed, bulky, or otherwise faulty knots in a warp give rise to many imperfections in cloth, besides hindering production by causing frequent stoppages of a loom to amend or remove these defects. During weaving, the long ends of knots are liable to become entangled with adjacent warp-ends, and thereby cause faulty shedding by interfering with the freedom of those threads. They are also a frequent cause of "floats" and other imperfections in cloth, and breakages of warp ends. Bulky knots also cause faulty shedding by catching or hooking on to adjacent warp-ends. They also hinder the free passage of threads, containing them, through the harness and reed, thereby causing them to "pull" and strain in cloth until they finally break. It has been affirmed that 75 per cent. of the breakages of warp-ends during weaving are directly due to imperfectly tied knots.

Provided knots in yarn are not of a character to impede weaving, or to produce serious imperfections in cloth, their presence in most fabrics is of little consequence. There are, however, certain classes of fabrics in which knots of any description are liable to produce serious consequences. They should, therefore be reduced to the lowest possible number, and those which are unavoidable should be neatly tied. For example, the presence of knots in velveteens and corduroys constitutes a source of danger during the operation of fustian cutting, by which the pile surface characteristic of those fabrics is produced. Knots in those fabrics are liable to cause the knife of a fustian cutter to deviate from its proper course, and to penetrate and injure the cloth.

In the manufacture of some fabrics, however, it is essential that knots of any description should be entirely absent: for example, the canvas cloth that is subsequently coated with rubber, and used in the construction of pneumatic tyres for bicycles, motor cars, and other vehicles; fabrics to be afterwards coated with rubber, or other non-porous material, to make them waterproof; fabrics intended for the production of card clothing or filletting (for carding and other machines for similar purposes employed in spinning mills), and many others. Card clothing consists of several layers of cloth cemented together, and coated on the upper surface with a layer of pure india-rubber, to provide the projecting wire points with a flexible or resilient foundation. The presence of knots in any of the fabrics just enumerated would not only impede the operation of coating them with the various non-porous materials, but they would also prevent the latter from being laid in a perfectly even sheet, and produce flaws by projecting above the surface. Weavers engaged in the production of such fabrics adopt special means to replace broken threads without resorting to knots.

It will now be sufficiently manifest that it is of the utmost importance to all concerned, that warps should be furnished to a loom as free from knots as possible, and that such as are unavoidable should be neatly formed with short tail-ends. These objects may only be attained by the use of superior raw material, and a reasonable amount of care on the part of operatives who have the manipulation of that material from the earliest to the last stage of its manufacture into cloth. As

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previously stated, breakages of yarn are most liable to occur during those operations in which yarn is subjected to individual tension, when the weak places give way under the strain. When a thread breaks, the operative is expected to repair the breach by finding and piecing the broken ends of the thread. This is usually performed by hand, with considerable dexterity, by experienced workers whose chief object is to save time, and avert loss of production and wages, oftentimes with an utter disregard of the consequences of imperfectly-tied knots. The broken thread is quickly joined, usually by what is termed

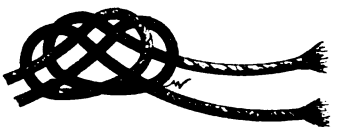

FIG. 32.—WINDER'S OR SPOOLER'S KNOT.

a winder's or spooler's knot, illustrated in Fig. 32, which shows the knot before being tightened. After tying a knot, the operative should break off the loose ends, so as to leave projecting tail-ends as short as possible, consistent with safety. Instead of that, knots are frequently pieced in an indifferent manner, and are left with long tail-ends.

The particular stage of manufacturing at which threads are most liable to break, and which is, therefore, productive of the greatest number of knots, is during the operation of winding yarn from any of its preliminary forms on to warpers' bobbins: this operation is usually the first one to be performed by the cloth manufacturer after receiving yarn from the spinner in the form of mule cops, twiner cops, on ring bobbins, doubling bobbins, or spools. Indeed, it is one of the functions of a cop or bobbin winding machine to detect such imperfections in yarn as are likely to prove impediments during subsequent operations, and to lead to their reparation. With this object, they are furnished with yarn clearer guides containing narrow slits through each of which a thread passes just before it enters upon a warper's bobbin. The function of a clearer guide is to prevent the passage of slubbings, knots, snarls, seed husks, or other impediments, which are caught by it; and if the obstruction is not easily removed, the thread breaks. Hence it is that breakages are more frequent at this, than at any other stage of manufacturing; and if they are repaired by carelessly and slovenly tied knots, the latter may lead to more serious consequences than the original defects which they are supposed to remove. If bad knots or other imperfections are allowed to pass this stage, their detection and removal during subsequent stages of preparation is very remote; for during winding, the threads are separate and independent units, and therefore under better observation than when they are grouped. It then devolves upon a weaver to remedy these defects, and to suffer the consequences of the carelessness or incompetency of those whose duty it was to prevent them. Some winders are paid a higher rate of wages to piece threads by what is known as a weaver's knot, illustrated in

FIG. 33.—WEAVER'S KNOT.

Fig. 33, and to clip the ends short. A weaver's knot is very secure, and not quite so bulky as a spooler's knot.

Chiefly with a view to ensuring perfectly-tied knots with short and uniform tail-ends, and also to facilitate the piecing of broken threads, some employers equip their operatives engaged in winding and similar operations with mechanical knotters, of which there are two distinct types that have met with some measure of appreciation by both employers and employees. Of these, that known as the

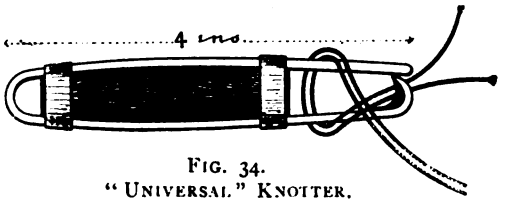

FIG. 34.
"UNIVERSAL" KNOTTER.

"Universal" knotter, illustrated in Fig. 34, is a simple device (costing two shillings each) consisting of a piece of steel wire, having one end formed with a hook sharpened on the inside to form a cutting edge. The wire is then bent to bring the hooked and straight ends together, and fixed in a handle either of wood, or else of white metal moulded upon it. It is made in several patterns to suit the different characteristics of the various textile threads.

This instrument does not itself tie a knot and cut off the ends automatically, but merely aids the operative to produce knots having uniformly short tail-ends. It may be used as a hand-tool carried by

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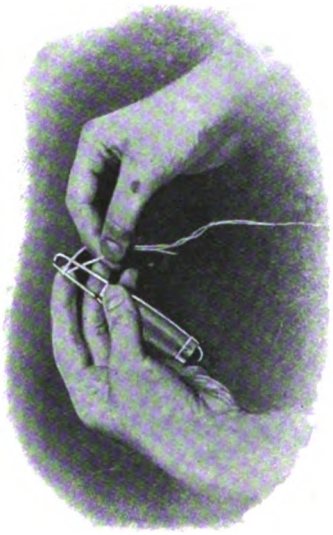

FIG. 36.

FIG. 38.

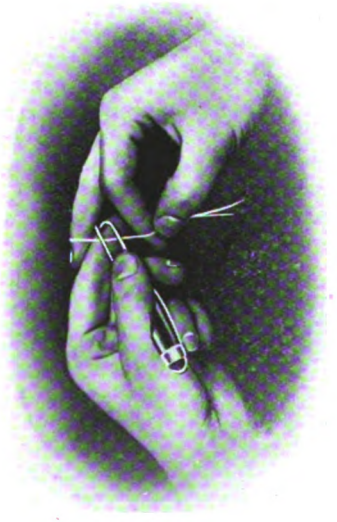

FIG. 35.

FIG. 37.

each operative, as illustrated in Figs. 35–39*: but if used by winders, a more approved and efficient plan is to fix several knotters on brackets secured to the guide or traverse rails of the winding machines, as illustrated in Fig. 40, with a knotter for every ten spools. If a knotter is employed as a hand-tool, it is carried in the left hand of the operative, with the hook on the first finger, and the haft towards the centre of the hand, as illustrated in Fig. 35. The two threads to be joined are taken between the thumb and first finger of the right hand, and placed *over* the first finger of the left hand, *underneath* the hook, as shown in the same figure. The permanent threads are then brought over the *top* of the hook by the second finger of the right hand, as seen in Fig. 36. The two ends held by the first finger and thumb of the right hand are crossed over the permanent

* For permission to use Figs. 35–40 the writer here expresses his thanks to Messrs. Cook & Co., Exchange Street, Manchester.

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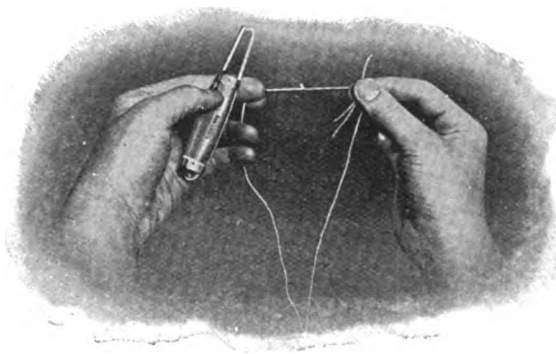

FIG. 39.

threads, and passed through the slot in the hook, as shown in Fig. 37; then, by smartly drawing the threads towards the sharp hook, as seen in Fig. 38, the knot is tied, and the loose ends cut, simultaneously. The severed waste ends are now withdrawn from the knot, which is of the same formation as a spooler's knot (illustrated in Fig. 32), with short tail-ends about one-eighth of an inch in length, as seen in Fig. 39. On attaining proficiency in the use of this tool, a knot may be tied by it in the space of three or four seconds, or about the same time as that occupied in tying a knot entirely by hand. The instrument is only recommended for use as a hand tool when it cannot be conveniently fixed to the machine with which it is used, as reeling and warping machines; but for the use of winders generally, it is found to be much more advantageous to fix a number to each machine in the manner illustrated in Fig. 40.

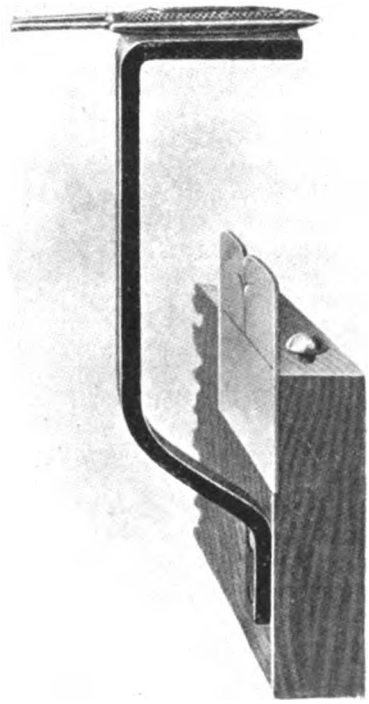

FIG. 40.—UNIVERSAL KNOTTER, FIXED TO GUIDE RAIL OF WINDING MACHINE.

By this plan of fixing knotters, both hands of the operatives are left quite free from obstruction, and the knotters are not liable to become injured, mislaid, or lost. In order to piece two threads, with fixed knotters, it is necessary to first remove a bobbin from its spindle, and rest it upon the guide rail, to leave both hands free to tie the knot and cut off the waste ends; after which the bobbin is replaced on its spindle. The operation of tying a knot, when the knotter is fixed, is performed by taking the extremities of both threads between the finger and thumb of the right hand; then taking hold of them by the finger and thumb of the left hand, with an interval of about three inches between the two points held. The threads are now placed *over* the wires, and the *left* hand passed first underneath and then over the top of the wires to the first position, so as to wrap the threads completely around the wires. The threads are then slipped by the *right* hand into the slot, and both hands drawn smartly forward, to tie the knot and cut off the waste ends simultaneously. The latter are then withdrawn by the right hand, leaving a perfectly tied knot with short tail-ends. The advantages claimed for this knotter by the makers are, that the prejudice of operatives is entirely overcome against carrying a knotter constantly in the hand; that, having the freedom of both hands, they can draw up the knot tighter and smaller, and produce one that is quite secure, with shorter tail-ends; that the speed of tying is considerably increased; and that the instrument cannot either get out of order or become lost.

Another type of knotter that has found considerable favour amongst manufacturers is that known as the "Barber" knotter, introduced into this country from America, about the end of the year 1901. The general appearance of this instrument is shown in Fig. 41. It is an exceedingly ingenious, well-constructed, though somewhat complex and

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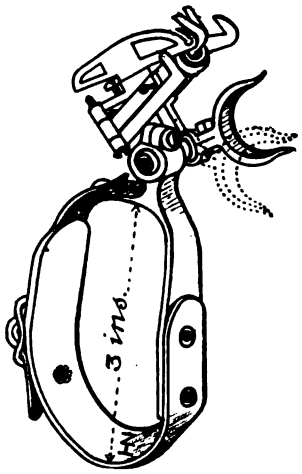

FIG. 41.—"BARBER" KNOTTER.

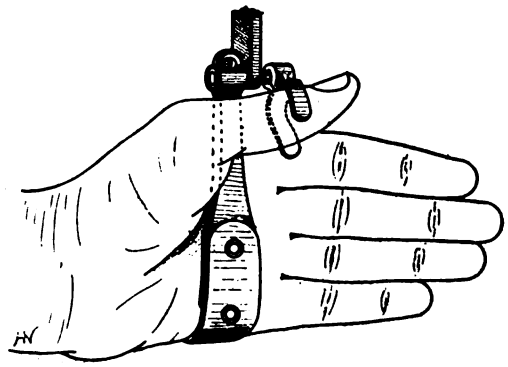

FIG. 42.—SHOWING HOW A "BARBER" KNOTTER IS STRAPPED ON THE HAND.

delicate piece of mechanism, comprising about thirty distinct parts, supported upon a handle that is strapped upon the left hand of the operative (as illustrated in Fig. 42), by whom it is constantly carried, during working hours, with the thumb placed in a thumb fork by which the knotter is actuated. It is made in three sizes—A, B, and C—to suit different counts and strengths of yarn, and weighs 4 oz., $5\frac{1}{16}$ oz., and 6 oz., complete, respectively. This type of knotter not merely aids in the tying of knots, but it actually ties the knot, tightens it, cuts off the waste ends, and releases the knot automatically, and in such rapid succession, as to accomplish all four movements in less than one second of time. This is performed by simply laying the two threads to be joined (with the free ends away from the operator) over a thread guide and a side arm, and smartly depressing the thumb fork, which may be subsequently returned to its first position at leisure. The kind of knot tied by this instrument is an ordinary spooler's knot, with short tail-ends of about one-eighth of an inch in length. When used by winders (each of whom requires to carry a separate knotter) it is not necessary for them to remove a spool or bobbin from its spindle in order to piece threads. This may be accomplished by first taking the threads coming from a cop (or other source of supply) by the right hand, as when piecing by hand. then stopping the warper's bobbin, by the left hand (supporting the knotter), and slightly lifting it to find its thread. The warper's bobbin is then allowed to drop back on its spindle, but is prevented from revolving by resting the left hand upon it, whilst the two threads are passed over the knotter, when the thumb fork is smartly depressed, and the threads are pieced by a neat knot with short tail-ends, ready for continuing winding.

It is sometimes urged against the adoption of the "Barber" knotter that its initial cost (£5 3s. nett) is prohibitive: that, being of delicate construction, it is easily liable to injury by falling, accidental knocks, or careless usage: that expense will be incurred in replacing broken or worn-out parts: that, being a separate instrument, it is liable to become mislaid, or lost: and, that it constitutes an impediment to the free use of both hands of the operative. On the other hand, the makers of the instrument claim that by its use the work of winders is greatly facilitated: that both they and weavers are capable of producing a greater quantity and better quality of work: that wear and tear of winding spindles and bobbins are reduced: that it reduces waste: and that it pays for itself in twelve months.

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ARMOURED CONCRETE.

By Lieut. HENRY J. JONES, A.O.D., A.R.C.Sc. (Lond.), Inspector of Ordnance Machinery.

OF the interesting features of modern constructive practice which call for appraisement, either from their extreme novelty or successful application, none holds so high a place as the unique adaptability of armoured concrete to the many and varied engineering requirements of recent times.

The term "armoured concrete construction" is used to denote any general scheme of construction in which a combination of concrete and steel is made to do duty more economically than would either steel or concrete if used alone; and in the discussion of economy we shall be led to include, not only initial cost, but also cost of maintenance, rate of depreciation, standard of labour, and rapidity of construction. With regard to the economy in initial cost of materials, and also in illustration of the striking influence of steel armouring used in the way to be hereafter explained, attention may be drawn to Fig. 1, which shows two beams designed to carry ordinary floor loads, the one made entirely of concrete, and the other of concrete with a sheet of expanded metal imbedded in

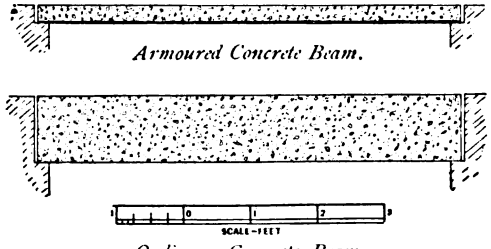

FIG. 1.—BEAMS, OF EQUAL STRENGTH, OF ARMOURED AND ORDINARY CONCRETE.

the tensile portion of the beam. The saving in mere weight of concrete alone is most striking; and when we remember that the adoption of floor beams entirely of concrete means an increase in thickness of nine inches, or supposing five to eight floors, an increase in the total height of the building (with extra cost of higher and heavier walls, together with heavier foundations to carry them), of from four to six feet, we see that even as regards initial outlay for materials, the introduction of steel armouring into concrete construction is of great importance. When we shall have considered the other items on our economic programme, the fact that armoured concrete construction is incomparably the best system at present known to engineers will be even more manifest. The most remarkable fact about the whole matter is, that the weight of properly disposed steel required to reduce the depth of our floor beam to one of equal strength in armoured concrete, is so insignificant. Comparing areas of steel and concrete exposed in cross-section, the steel is sometimes only ½ per cent., and rarely rises above 1 or 1½ per cent. of the area of the concrete; and as the cost of expanded metal is only from 2*s*. 5*d*. to 1*s*. per yard super, we see that the cost of the steel armouring is very small compared with the saving in weight of concrete which it produces.

Subsequently we shall treat of the systems and methods of calculation in detail; but a good idea of armoured concrete construction can be obtained from Fig. 2, which is an isometrical projection of a portion of a pier strong enough to carry the heaviest railway traffic. The disposition of the steelwork is shown in the piles, the main girders, and beams; and the manner in which the steel rods running along the tensile or bottom side of the girders and beams are bent up over the top of the pile, which is here the tensile member (the beams being continuous), and then down again to the bottom of the girders and beams, is most instructive.

The use of armoured concrete as a material of construction has much to recommend it. The materials can be cheaply procured and transported, and can be adapted to almost any conditions, being suitable for floors and beams, piles and tunnels, pipes and aqueducts, reservoirs and bridges. Armoured concrete possesses excellent fire-resisting properties, is as economical in almost any neighbourhood as bricks and mortar, and besides combining strength with durability, is able to resist the action of rain, frost, and smoke; in a general way it may be dealt with by local and unskilled labour, although a considerable amount of skill and experience in handling contractor's plant, as well as a high standard of carpentry, are required for the temporary

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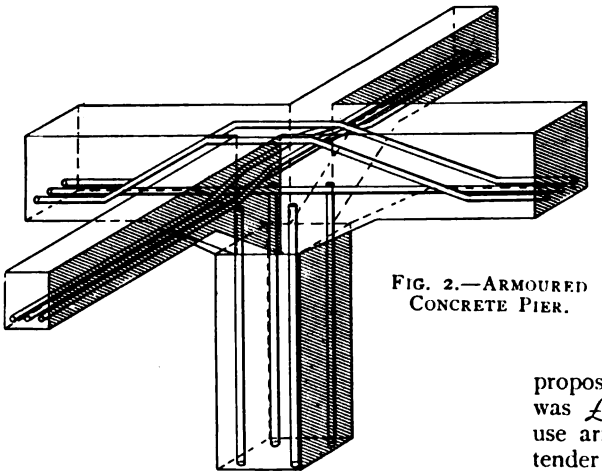

FIG. 2.—ARMOURED CONCRETE PIER.

work of erection. A structure in armoured concrete needs no expenditure for maintenance, and thus has a great advantage over steel work, which requires to be painted every few years to prevent rapid deterioration. For sea structures, armoured concrete is far superior to either wood or steel, and less costly than stone. It does not suffer from the ravages of the marine pests, *Teredo navalis*, *Chelura terbrans*, and *Limnoria terebrans*, and there is no need to use corrosive sublimate, chloride of zinc, or creosote for protective purposes.

Labour in armoured concrete is cheaper and more expeditious than that in steel, for steel rods or expanded metal are easily obtained, and concrete quickly prepared; whereas to obtain special castings in steel is a costly and laborious process, necessitating highly skilled workmen, and a loss of available section due to rivetting. A girder in armoured concrete can be made and fixed in position before steel girders would be half-finished; and warehouses of seven and eight floors, supported by armoured concrete girders and columns, have been erected in a few months, whereas it would have taken three times as long to erect a similar building in the usual manner with steel girders and columns. Bridges built of armoured concrete admit of very flat arches, which would be impossible in brick and stone, and we thus are able to secure the advantage of greater waterway compared with arches of the same rise. Pipes and conduits can be made *in situ*, to any length, diameter, and section, being strong enough to carry the heaviest vehicular traffic, and comparing favourably in price with similar work in brick and stoneware.

Armoured concrete structures are, for the same strength, lighter than those in masonry and stiffer than those in steel, and in general the adoption of armoured concrete means a saving of from 15 to 20 per cent. on the initial outlay, and a further saving due to the permanence of the work and its insignificant need for maintenance. Some actual figures may be quoted. The bridge across the Aisne at Soissons cost £8,270 in armoured concrete. The estimate for the bridge in masonry was £10,145, and in steel £9,730. The tender supplied for a proposed pier on the South Coast, in steel, was £7,475; it was ultimately decided to use armoured concrete, and the alternative tender was £5,784.

As to the cost of work in armoured concrete, we may take, as a good average figure, 5*s.* 4*d.* per foot cube of concrete, this price including all steel rods and other armouring, all shuttering, material and labour, and all subsequent testing, but excluding the driving of piles. For the latter we may take, in ordinary circumstances, 2*s.* 6*d.* per foot run of the length of the pile driven, this price including all contingent labour and plant.

In the face of the fact that concrete possesses so many advantages over other materials of construction, it is interesting to inquire as to the reason why it had not found general favour until very recent years. Concrete was used, as a material of construction, long before other artificial substances, now recognised as the legitimate material of the constructive engineer, were known. The Romans were probably the first to use it to any extent, evidence of their acquaintance with it dating back anterior to 500 B.C. They exhibited great skill in its treatment, principally using it as a core or filling between masonry facings. According to Potter, buildings with concrete foundations have been found in Mexico, and in the Italian colonies of Magna Græcia. The dome of the Pantheon, built by Agrippa, 27 B.C., was constructed entirely of concrete; and in the House of Vestals, a floor of twenty feet span was a simple slab of concrete fourteen inches thick, supported on corbels projecting from the walls. The Baths of Caracalla also give evidence of extensive concrete vaults. The foundations of Salisbury Cathedral, constructed over 800 years ago, are of concrete; and the only remaining fragments of Old Sarum show evidences of its use. Corfe walls are largely composed of it, and Reading Abbey walls were apparently faced with ashlar on both

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sides, and the core or backing made of concrete, with the result that the stone has perished, but the concrete, which was intended to play a secondary part, still remains.

Despite its evident antiquity and suitability for many classes of work, the merits of concrete were not generally recognised for many centuries, and we shall probably find this to be due, not so much to inherent defective properties of the concrete, as to the limitations placed on the method and manner of its manufacture by the lack of suitable plant then at disposal. Previous to the invention of Portland cement by one "Joseph Aspdin, bricklayer of Leeds, in the County of York," powerful and quick-setting limes were unknown, and concrete manufacture was restricted to the use of materials corresponding to the old Roman *pozzuolana*, although of totally different origin. Added to this absence of a suitable matrix, there was also an entire absence of any mechanical appliances to facilitate construction, and to reduce the aggregate employed to a suitable size. Hence it came about that in this country concrete construction was almost entirely abandoned, and foundation work came to be done by the costly system of piling and planking. With the introduction and extensive manufacture of Portland cement, as well as mechanical crushers for reducing the aggregate, we might have expected concrete construction once more to have found favour and adoption. It was not so. Engineers found concrete a very uncertain material to deal with. It would fail suddenly under transverse strains, and thus its use, when tensile strains had to be borne, became a matter of great difficulty and no little danger, because, to ensure sufficient safety, great depth had to be given to beams and floors, which added considerably to the total weight and cost, and to the height of the structure. Subsequent experience and experiment established the fact that the strength of concrete in tension is only about one-tenth its strength in compression, which could reasonably have been expected when we remember that in tension we depend for our strength mostly on the tensile strength of the matrix, which is low, and in compression on the compressive strength of the aggregate, which is high.

Hence arose the question—in what way can we treat concrete so that its high compressive strength can be utilised without, at the same time, placing any reliance on its low tensile strength? The problem was first solved, accidentally, by Jean Monier, a gardener of Paris, who in 1876 invented the system of construction which has since been known by his name. Ward, of New York, had, however, previously (in 1875) constructed a building in which, "not only all the external walls, cornices, and towers were constructed of cement concrete, but all the beams and roofs were exclusively made of it, reinforced by light iron beams and rods." The introduction of steel into concrete was thus found to give, indirectly, the quality which the concrete lacked in itself; and such an introduction has its warrant in the fact that concrete construction without a tension member can be used only in a limited number of cases where economy in weight and cost do not enter as controlling factors.

In a general way we may take it to be axiomatic that economic structural design aims at such a distribution of forces, and members disposed to bear them, that, under the conditions of greatest allowable strain, each member or portion of a member shall bear just such a force as that for which it is best fitted, all members shall be stressed to their safe limit at the same time, and the cost of the structure shall be a minimum consistent with the other conditions being satisfied. Armoured concrete construction is eminently in accordance with these principles.

Experiment has shown that the compressive strength of concrete is about ten times its tensile strength, and that steel has about the same strength in tension and compression. A given volume of steel costs about fifty times as much as the same volume of concrete, and for the same sectional area steel will bear in compression thirty times the load borne by concrete in compression, and three hundred times the load borne by concrete in tension. Hence, for duty under compression only, concrete will carry a given load at six-tenths the cost required to support it in steel. On the other hand, to carry a given load by concrete in tension would cost six times as much as to support it with steel. Hence if we endeavour to arrange the members of our structures in such a way that the compressive stresses are all borne by the concrete, and the tensile stresses by steel suitably embedded in the concrete, we shall be using each material for the purpose for which it is the cheapest and the best fitted, and thus fulfil the above-stated principle of economic design. It may be stated here, that the shearing resistance of concrete is also very inadequate, and hence in the most approved armoured concrete designs, the shearing stresses are borne by

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small steel rods and stirrups embedded in the concrete.

Having satisfied ourselves that the novel combination of steel in concrete is, theoretically, a justifiable one, the question naturally arises as to the effects of age, moisture, changes of temperature, on the mutual relations between the steel and the concrete. Is the adhesion between the two materials such as to prevent slip when distortion takes place? Will water, percolating through the concrete (a substance not impervious to it), cause the steel to rust and deteriorate? Will the combination stand shock, the effect of rolling loads, and the changes of temperature, both natural and artificial, without permanent injury and decay? To all these questions practice gives a positive and favourable answer.

With regard to adhesion, it may be noticed that the force required to separate a rod from the concrete in which it has been embedded varies from 550 to 650 lbs. per square inch. Since this is above the figure assumed for the safe working limit of concrete in compression, no fear of failure through slip occurring between steel and concrete need be entertained. The use of expanded metal and twisted rods offers a better means of securing a good adhesion than the use of flat bars or round rods. As far as experience goes, steel embedded in a good alkaline concrete will not rust in any way when exposed to the action of moisture and air; at any rate, if there is a deteriorating action, its extreme slowness does not enter as an objection against the use of steel armouring. Again, no disintegration of the concrete occurs under severe shock or the most violent changes of temperature. Piles of armoured concrete, up to sixty feet in length, have been driven and withdrawn without any injury whatever. And the result of experiment and experience on armoured concrete work has been to show that the coefficient of expansion of steel and concrete are almost identical, and independent practically of the proportion of cement used. The expansion of such structures must, however, be provided for, in order to prevent undue strains and subsequent surface cracks. In this connection rich concretes are not recommended, as they crack more readily than concretes of poorer composition. It is further advisable to cover the concrete where possible, and to provide expansion joints, as well as avoiding sharp angles and fixed beam ends where free ones could be as suitably employed. Slow-setting cement of good quality is imperative, and the main thing about the concrete is not so much its composition as the care with which it is made, applied and rammed, when once the materials have been chosen. The only objection to armoured concrete is an æsthetic one. The appearance of the finished work is dull and colourless, without any of the distinctive tones and colour which we have usually associated with engineering work in brick and stone, especially when the work has been of a high standard. But in circumstances where appearance is an inconsiderable quantity, for piers, jetties, foundations, etc, armoured concrete construction has claims very far in advance of any material now at the disposal of the constructional engineer.

(*To be continued.*)

DEMAGNETISATION OF THE EARTH.

In the *Physical Review* for February, 1905, L. A. Bauer gives an account of an investigation which he has conducted with respect to the variation of the magnetic moment of the earth. The secular variation of the earth's magnetism has been determined, between 1890 and 1900, at a number of land stations fairly uniformly scattered over the earth between the latitudes 60° S. and 60° N.; and on submitting the results to mathematical analysis, Bauer finds that the magnetic moment of the earth is diminishing in value, and will probably fall to half its present value in the course of the next 1,600 years. The results are confirmed by a study of the magnetic charts for 1843 and 1885, although the evidence in this case is less conclusive, owing to lack of experimental data.

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART VII.—THE DYNAMICS OF TUBES OF FORCE.

By EDWIN EDSER, A.R.C.Sc.

IN the January, February and March numbers of TECHNICS I briefly outlined the theory which forms the basis for measurements connected with the electric and magnetic circuits. So far as these measurements are concerned, we may look on electric and magnetic tubes of force as being equally real; since, however, electricity in motion produces a magnetic field, we are logically forced to the conclusion that the magnetic tubes of force are produced by the motion of electric tubes of force; a general idea of the process involved was given in the November number of TECHNICS (No. 11, p. 466). It now becomes necessary to carry our reasoning a step further, and to determine the quantitative properties of electric tubes of force in motion; in particular, to determine the velocity with which electric tubes of force move.

Let A B (Fig. 1) represent two plates forming a condenser; it will be assumed that this condenser is kept charged to a constant potential, so that when an electric current flows out of it, electric tubes of force are introduced as quickly as the electric current carries others away. Let the difference of potential between A and B have the constant value V; *i.e.*, V ergs of work must be performed in carrying unit quantity of electricity from B to A. Let us now suppose that two flat metallic plates, shown in section in Fig. 1 as CD and EF, are respectively connected to A and B; it will be assumed that these plates are perfect electrical conductors, that they extend to an indefinite distance towards the right, and that they are very broad in a direction perpendicular to the plane of the paper, so that lines of force extending from one plate to the other will be straight and perpendicular to the plates. Let us further suppose that two strips S, S (Fig. 2), each a centimeter wide, are isolated by means of fine cuts in the two plates, the strips being opposite to each other, and extending in the direction from C to D or E to F (Fig. 1); then the tubes of force will extend straight across from one strip to the other.

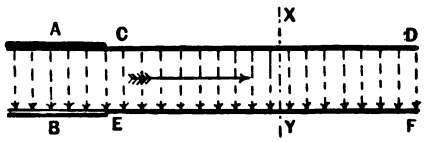

FIG. 1.—LINES OF FORCE PROJECTED FROM PLANE CONDENSER INTO SPACE BETWEEN TWO FLAT STRIPS.

On connecting the plates CD and EF to A and B, lateral repulsion will constrain some tubes of force to pass from between A and B into the space between the plates CD and EF, and then to travel away towards the right. These tubes will be as closely packed in the space between CD and EF as they were between A and B; as far as the tubes have travelled there will be a difference of potential V between the plates, no drop of potential occurring in the plates, since these are perfect conductors. Confining our attention to the two strips S, S, let a quantity Q of electricity flow from A on to the upper strip in one second; then since unit c.g.s. current flowing for one second is equivalent to the passage of unit quantity of electricity across any section of a conductor, it follows that the current flowing from A on to the upper strip is equal to Q c.g.s. units. (The c.g.s. unit of current used in this investigation is the electro-magnetic unit defined in TECHNICS, No. 13, January, 1905, p. 41).

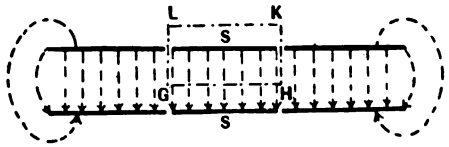

FIG. 2.
CROSS SECTION THROUGH X Y, FIG. 1.

From the above it will be seen that the upper strip gains Q positive units, and the lower strip gains an equal number of negative units of electricity per second. The condenser AB gives up to the strips Q units of charge, at a potential V per second, and therefore the *loss of energy to the condenser* is equal to VQ

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ergs per second. If the tubes associated with the charge Q travel from left to right along the strips with a velocity v, a length v of the strips will become charged to a potential V in a second; if these tubes of force were brought to rest, their energy would be equal to $(VQ)/2$ (TECHNICS, No. 12, December, 1904, p. 576), so that the static energy of the tubes moving from left to right between the strips amounts to only half of the energy given up by the condenser AB. But since the tubes possess inertia and are in motion, they will possess a certain amount of kinetic energy. No energy is used up by friction between the ends of the tubes and the strips (the strips being perfect conductors), whence it follows that *the total energy of the tubes must be half static and half kinetic*, each being equal to $(VQ)/2$.

The static energy of the tubes of force comprised in a cubic centimeter of the space between the strips is equal to

$$(\kappa N^2)/(8\pi K) \quad . \quad . \quad . \quad . \quad . \quad (1).$$

(TECHNICS, No. 12, December, 1904, page 579), where N is the number of tubes of force per square centimeter in the space between the strips, κ is the dielectric constant of the æther, and K is the specific inductive capacity of the material medium between the strips. (For the æther K = 1.) To determine N, notice that the quantity Q charges a length v of the upper strip, the breadth of this strip being one centimeter; hence Q/v is the charge per square centimeter of either strip, and the number of tubes of force leaving or entering a square centimeter is equal to $(4\pi Q)/\kappa v$ (TECHNICS, No. 12, December, 1904, p. 575), so that

$$N = \frac{4\pi Q}{\kappa v} \quad . \quad . \quad . \quad . \quad (2).$$

We must now determine the kinetic energy of the electric tubes of force. The motion of the tubes from left to right (Fig. 1) will produce magnetic lines of force extending downwards through the plane of the paper in the space between the strips (TECHNICS, No. 11, November, p. 468); since there are practically no moving tubes of force in the space above the upper strip, or in that below the lower strip, the only place where there will be any sensible magnetic field due to the current carried by the strips is in the space between these. Let the magnetic field between the strips be equal to B magnetic lines per square centimeter, the medium between the strips having a permeability equal to μ (for the æther $\mu = 1$). Then the magnetic energy per cubic centimeter of the space between the strips is equal to $B^2/(8\pi\mu)$ (TECHNICS, No. 12, December, 1904, p. 579). Since the magnetic field is due to the motion of the electric tubes of force, the energy of the magnetic field must be equal to the energy of motion (or kinetic energy) of the electric tubes of force; hence the electric tubes of force contained in a cubic centimeter possess, in virtue of their velocity v, a kinetic energy equal to

$$B^2/(8\pi\mu) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

It remains to determine B in terms of N, the number of electric tubes per square centimeter.

As explained on p. 345, the current flowing along the upper strip is equal to Q electromagnetic c.g.s. units; hence if we carry a unit N pole once round any path which embraces the upper but not the lower strip, the work done will be $4\pi Q$ ergs (TECHNICS, No. 14, February, 1905, p. 124); from (2), this is equal to $\kappa N v$. Let us choose the path G H K L (Fig. 2), along which the unit N pole is carried, so that it is rectangular, lying in a plane perpendicular to the length of the strips; let two opposite sides G H and K L of the rectangle lie respectively above and below the upper strip, each being one centimeter long; the remaining two sides being of any convenient length. Then, in traversing the path G H K L, work will be done only in the one centimeter side G H, there being no component magnetic field parallel to any one of the other sides. Since the force on a unit pole when placed in a magnetic field of B lines of force per square centimeter, the medium having a permeability μ, is equal to B/μ, the work done in carrying a unit pole round the path described above is equal to $(B/\mu) \times 1$. Thus,

$$\kappa N v = B/\mu.$$

From this we conclude that the magnetising force in the space between the strips is equal to $\kappa N v$. Also,

$$B = \kappa \mu N v.$$

Hence from (3), the kinetic energy of the electric tubes of force contained within a cubic centimeter of the space between the strips is equal to

$$\frac{B^2}{8\pi\mu} = \frac{\kappa^2 \mu N^2 v^2}{8\pi} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Since the static and kinetic energies per unit volume of the tubes of force are equal, it follows from (1) and (4) that

$$\frac{\kappa N^2}{8\pi K} = \frac{\kappa^2 \mu N^2 v^2}{8\pi} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$\therefore v = \sqrt{\frac{1}{K\kappa\mu}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

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Since the value obtained for v does not depend on N, it follows that the velocity with which the tubes travel is independent of the difference of potential between the strips, and of the current flowing along either strip; it depends merely on the properties of the medium between the strips.

For the æther, K and μ are both equal to unity: the values of these constants are only very slightly greater than unity for air. Thus, if v_o is the velocity of the tubes in the free æther (and practically in air),

$$v_o = \sqrt{\frac{1}{\kappa}}.$$

An electric circuit composed of flat strips has been chosen merely to obtain the conditions which admit of the readiest calculation. A more extended investigation shows that the velocity of the electric tubes of force still has the above value when the circuit is formed of wires, provided these are perfect conductors: if the circuit possesses resistance, there will be a backward drag on the ends of the tubes of force, and these will move with a slightly smaller velocity.

It is possible to measure the value of κ, and hence to determine the value of v_o. If a condenser is formed of two flat plates, each of area A, placed at a uniform distance d from each other, with nothing but air between them, then the capacity of this condenser is equal to $\kappa A/(4\pi d)$ (TECHNICS, No. 12, December, p. 576). In this expression A and d can be found by direct measurement, and the only unknown quantity is κ. Now by charging the condenser and then discharging it through a ballistic galvanometer,* the absolute value of the capacity can be obtained; hence it is obvious that the value of κ becomes definitely known. Many investigators have determined the value of κ, using various methods; as a result, it is found that $v_o = \sqrt{1/\kappa}$ is equal to the velocity of light. Table I. comprises the results of the most accurate experimental determinations of $\sqrt{1/\kappa}$ and of the velocity of light.

When a charged body is moved, it of course carries its tubes of force with it; since each tube of force is endowed with inertia, the body will possess a greater apparent mass when charged than when uncharged. We may now determine the mass (or inertia) per unit length of a tube of force. The right-hand side of (5) gives the kinetic energy per unit volume of a medium of permeability μ comprising N tubes of force per square centimeter, moving with any velocity v cms. per sec.; substituting $\mu = 1$ (for air or the free æther), $\kappa = 1/v_o^2$, where v_o is the velocity of light, we find that the kinetic energy per cubic centimeter

$$= \frac{N^2}{8\pi v_o^4} v^2.$$

Now the kinetic energy is equal to half the mass into the square of the velocity of a body; from this we conclude that the mass per unit volume of the tubes of force is equal to

$$N^2/(4\pi v_o^4) \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Let the N tubes pass normally into one face of a centimeter cube, and normally out at the opposite face; then since the N tubes, each 1 cm. long, together occupy the space of a cubic centimeter, each tube occupies the space of (1/N) cubic centimeter. Therefore the mass per unit length of a tube is found by dividing (6) by N, when we obtain $N/(4\pi v_o^4)$. The sectional area of the tube is equal to (1/N) square centimeter, so that we find *the mass per unit length of a tube of force varies inversely as its sectional area.* It has previously been proved (TECHNICS, No. 12, December, 1904, p. 577) that the tension of a tube of force varies inversely as its sectional area, so that the mass (or inertia) per unit length, and the tension of a tube of force, are both altered in the same proportion when the sectional area of the tube varies.

From the above reasoning, the function of the conductors forming an electric circuit will be readily understood: the energy

* I hope to explain this, and other absolute electrical measurements, in future articles.

Determination of $\sqrt{1/\kappa}$.	
Experimenter.	Result.
Himstedt	$3{\cdot}0057 \times 10^{10}$
Rosa	$3{\cdot}0000 \times 10^{10}$
J. J. Thomson	$2{\cdot}9960 \times 10^{10}$
H. Abraham	$2{\cdot}9913 \times 10^{10}$
Pellat	$3{\cdot}0092 \times 10^{10}$
Hurmuzescu	$3{\cdot}0010 \times 10^{10}$
Fabry and Perot	$2{\cdot}9973 \times 10^{10}$

Determination of Velocity of Light.	
Experimenter.	Result.
Fizeau	$3{\cdot}1500 \times 10^{10}$ cms./sec.
Cornu	$3{\cdot}0040 \times 10^{10}$ cms./sec.
Young and Forbes	$3{\cdot}0040 \times 10^{10}$ cms./sec.
Foucault	$2{\cdot}9800 \times 10^{10}$ cms./sec.
Michelson	$2{\cdot}9985 \times 10^{10}$ cms./sec.
Newcomb	$2{\cdot}9986 \times 10^{10}$ cms./sec.

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is transmitted by the moving tubes of force, and the conductors simply act as guides to the ends of the tubes of force. It is instructive to picture the process by which an electric signal is transmitted by a submarine cable; in this case the electric tubes of force extend from the inner core of the cable to the sea water in contact with the external surface of the insulating sheath, and travel perpendicular to their lengths from one end of the cable to the other. Hence it is clear that the energy of the impulse is transmitted through the insulating sheath of the cable, and the conducting core simply serves as a guide and fritters away some of this energy by a property analogous to friction. The function of the conducting wires of an electric is thus not unlike that of the rails which guide a locomotive engine on its journey.

Fig. 3 shows the tubes of force projected from a charged condenser, and travelling along in the space between the wires forming an electric circuit. When a tube reaches the right-hand end of the circuit, where the upper and lower wires are connected, its two ends approach each other; as the length of a tube diminishes, its sectional area also diminishes, with the result that the energy of the tube remains constant; the two ends of the tube pass each other, the length of the tube then increases, and the tube travels back towards the condenser. We must now inquire what happens when the upper and lower wires in Fig. 3 are not

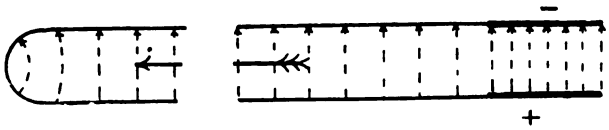

FIG. 3.—ELECTRIC LINES OF FORCE IN CLOSED CIRCUIT.

connected at their right-hand ends, but terminate in small balls separated by a space which may be called a spark gap (Fig. 4).

As the electric tubes projected from the condenser into the circuit reach the spark terminals, their inertia causes them to spread out on the farther side of the spark gap; the broken lines in Fig. 4 indicate the positions simultaneously attained by a number of tubes, or the positions successively attained by a single tube. The small arrows indicate that the parts of the tubes on the right-hand side are travelling away from the spark gap with a velocity which we have found to be equal to that of light. The density of the tubes in the space immediately between the spark terminals increases from moment to moment, and

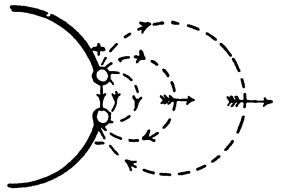

FIG. 4.—ELECTRIC LINES OF FORCE SPREADING OUT FROM SPARK GAP.

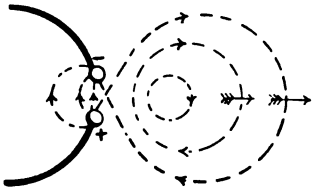

FIG. 5.—LINES OF FORCE AFTER SPARK HAS OCCURRED.

therefore their tension increases; when the tension increases to a certain value, it is sufficient to pull charged particles (probably of atomic or ultra-atomic dimensions) from the spark balls, and some of the tubes between the spark balls shrink to molecular dimensions, their energy being converted in heat: this constitutes the electric spark. The spark renders the space between the balls conductive, and the ends of the longer tubes of force are forced across the spark gap, as shown in Fig. 5. Thus the ends of the longer tubes of force cross each other; at the point where they cross coalescence occurs, with the result that a closed loop is set free, whilst a short length of the tube is left extending from the lower to the upper spark terminal. The tube extending from the lower to the upper ball returns to the condenser, in the manner already explained; after a time the condenser will thus receive a reverse charge. The right-hand side of each closed loop is travelling away from the spark gap with a velocity equal to that of light; its inertia will prevent it from losing its velocity. Meanwhile the charge of the condenser having become reversed, the tubes will be projected from the condenser toward the spark gap: these tubes, extending from the lower to the upper spark terminal, will spread out on the right of the spark gap, thus pressing against the left-hand side of the closed loops, which also extend upwards; the repulsion between tubes extending in the same direction prevents contact and coalescence. Hence the side of a closed loop near the spark gap is pushed toward the right, and ultimately acquires a velocity equal to that of light; the whole loop now travels away to the right with the velocity of light.

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diagrams* in Fig. 6; these represent the electric tubes of force in the neighbourhood of a spark gap during an oscillatory discharge such as that at present under discussion. Let the time of a complete oscillation (*i.e.*, the time required for the condenser to twice reverse its charge, thus returning to its original condition) be equal to T; then Fig. 6, *a*, represents the tubes of force at a time equal to (T/8) after the tubes of force first arrive at the spark terminals; in Fig. 6, *b*, for the time (2 T/8), the tubes are seen to have expanded away from the spark terminals; a still greater expansion having occurred in Fig. 6, *c*, for the time (3 T/8). In Fig. 6, *d*, for the time (4 T/8), the ends of the tubes have crossed the spark gap, and closed loops have been set free. In Fig. 6, *e*, for the time (5 T/8), reversed tubes extending across the spark gap are beginning to expand away from the gap, pushing the inner sides of the closed loops before them; in Fig. 6, *f*, *g*, *h*, corresponding to times (6 T/8), (7 T/8), and (8 T/8), the closed loops are seen to approximate to two concentric semicircles with their free ends joined, moving away with a velocity approximating to that of light. One complete oscillation has now been completed. Fig. 6, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, represents the course of the tubes during a second oscillation. In all cases the tubes near the spark gap are not shown, a small circle serving to isolate the space near the spark gap; further, the tubes are not represented when they pass beyond the outer dotted circle.

The way in which electric tubes of force, projected from a spark gap, are utilised in wireless telegraphy, has been lucidly described by Dr. J. A. Fleming, F.R.S. (TECHNICS, No. 11, November, pp. 444–450 and No. 12, December, pp. 562–567), and need not be further alluded to here.

The velocity of the tubes of force has been determined experimentally, by Hertz and others, in a manner to be subsequently described: it has been found to be equal to the velocity of light, as predicted by theory.

The fact that electric tubes of force travel with a velocity equal to that of light, suggests that light itself is due to the motion of electric tubes of force. In passing from one side to the other of one of the closed loops shown in Fig. 6, we pass from a point where the electric field (force per unit charge) has a certain positive value to a point where the field has an equal negative value. Imagine a straight line of indefinitely great length to be drawn from the middle of the spark gap, at right angles to the line joining the spark terminals; then, at any instant, the electric field will be alternately positive and negative as we proceed along this line, and at any particular point in the line the field will twice pass through all intermediate values between a maximum positive and a maximum negative value in the time T. The distance between a point in the line where the field has a maximum positive value, to the nearest point at which it has an equal maximum positive value, is called the wave length of the radiation, and is denoted by λ. Now in the time T (the period of the electrical oscillation), the tubes of force producing the maximum field at a point will move through the distance λ, so as to produce the next maximum; hence we have

$$v\,T = \lambda,$$

where v is the velocity of the tubes, which has been found to be equal to the velocity of light. Hence, the smaller the value of T, the smaller will be the value of λ. It has been found possible to produce electric waves with a length as small as 3 mm.;* if, however, we could produce waves with a length between 0·0004 and 0·0008 mm., these waves would constitute light. We know that light is produced when the atoms of a material substance are set in violent vibratory motion, and it is not difficult to picture what occurs in this case. Imagine two very small bodies, one charged positively and the other negatively. When these bodies are very close together, the tubes of force extending from one to the other will be confined, for the most part, to the space immediately between the bodies. If, now, we imagine the bodies to be quickly drawn apart, the tubes of force will expand outwards in the manner shown in Fig. 6, *a*, *b*, *c*; if the bodies then approach and ultimately pass each other, the tubes will cross each other and coalesce, giving rise to closed loops similar to those shown in Fig. 6, *d*. If the bodies now once more recede from each other, their tubes of force will expand outwards; and, since they extend in the same direction as the inner sides of the closed loops previously formed, these will be pushed outwards. Thus Fig. 6, *a* to *q*, will represent the tubes of force due to two oppositely charged bodies vibrating to

* "On the Vibrations in the Field round a Theoretical Hertzian Oscillator." By Karl Pearson, F.R.S., and Alice Lee, B.A., B.Sc. Phil. Trans., Vol. 193, pp. 159–188.

* See "Light for Students." By E. Edser. (Macmillan and Co.) pp. 348.

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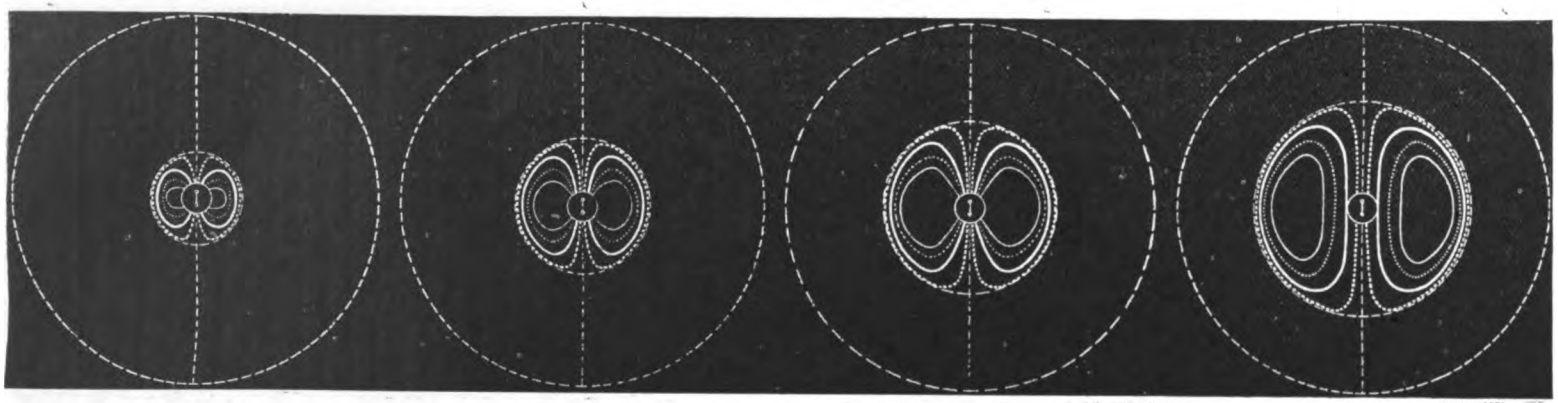
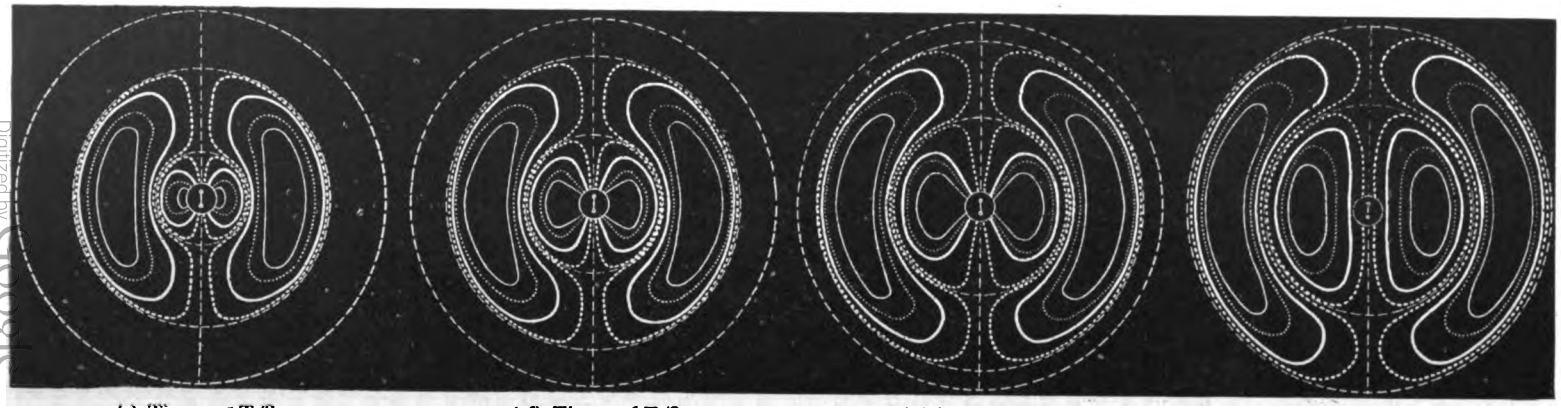


(*a*) Time = T/8. (*b*) Time = 2 T/8. (*c*) Time = 3 T/8. (*d*) Time = 4 T/8.



(*e*) Time = 5 T/8. (*f*) Time = 6 T/8. (*g*) Time = 7 T/8. (*h*) Time = 8 T/8.

FIG. 6.—SUCCESSIVE POSITIONS OF ELECTRIC LINES OF FORCE, IN NEIGHBOURHOOD OF SPARK GAP.
First complete oscillation of discharge.

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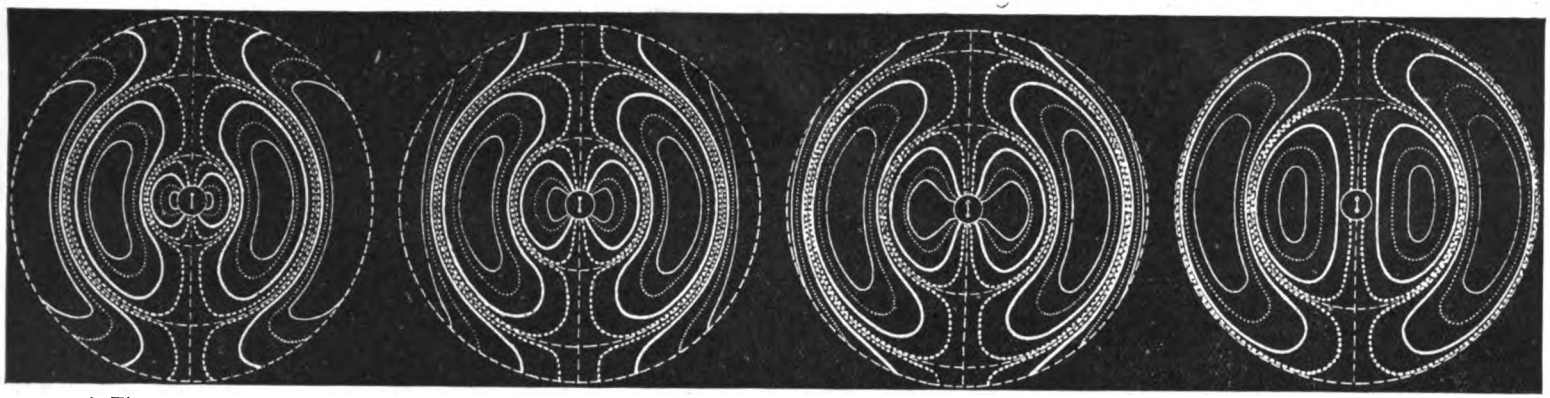
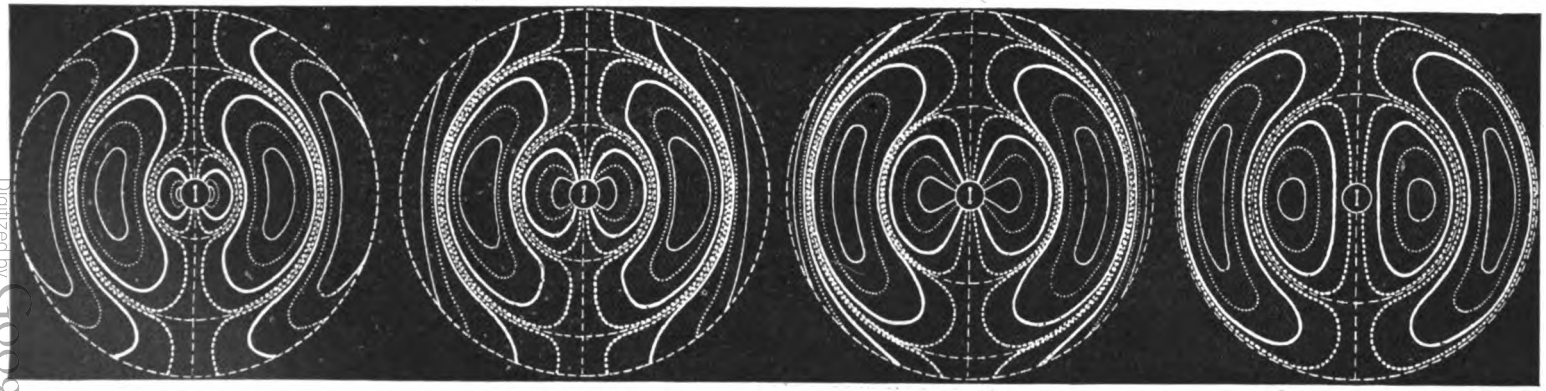


(*j*) Time = T + (T/8). (*k*) Time = T + (2 T/8). (*l*) Time = T + (3 T/8). (*m*) Time = T + (4 T/8).



(*n*) Time = T + (5 T/8). (*o*) Time = T + (6 T/8). (*p*) Time = T + (7 T/8). (*q*) Time = T + (8 T/8) = 2 T.

FIG. 6.—(*Continued.*)
Second complete oscillation of discharge.

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and fro, in such a manner that the two recede from each other, then approach and pass each other, and then once more recede, and so on. If the time occupied by a complete to-and-fro vibration lies between $1 \cdot 3 \times 10^{-15}$ second and $2 \cdot 6 \times 10^{-15}$ second, the wave length of the resulting radiation will lie between 0·0004 mm. and 0·0008 mm., *i.e.*, the radiation will constitute light. It is probable that an atom is composed of a number of charged particles, and the vibrations of these entail the projections of closed tubes of force which constitute light.

It is known that light travels more slowly in a transparent material medium than in a vacuum; the ratio of the velocity of light in a vacuum to its velocity in a material medium gives the refractive index of the medium. Now from equation (6), p. 346, it appears that the velocity of propagation in a medium of specific inductive capacity K, ($\mu = 1$) is equal to $\sqrt{1/K\kappa}$, and the velocity of propagation in a vacuum is equal to $\sqrt{1/\kappa}$; hence the refractive index of a medium is equal to $\sqrt{K}$. When, however, the period of the waves is comparable with the period of vibration of the charged particles constituting the atom of a substance, this law no longer holds; reasoning similar to that which explains dispersion on the elastic solid theory of light* must be employed. For long waves the refractive index of a substance is very nearly equal to the square root of its specific inductive capacity.

* See "Light for Students." By E. Edser, pp. 375.

(*To be continued.*)

CONTACT-RESISTANCE OF CARBON BRUSHES.

ALMOST important departure in connection with dynamo design was made when carbon brushes were introduced. With metal brushes, sparking can be avoided only by altering their lead with every variation of load. When carbon brushes are used, and the dynamo has been suitably designed, absolutely sparkless running may be secured for all loads, with fixed brushes. It is perhaps not too much to say that the present success in the design and construction of large traction generators is due to the use of carbon brushes.

Their superiority to metal brushes is due to several causes. In the first place, metal brushes, when greatly heated, are liable to fuse at the tips, with the result that the commutator becomes pitted. In addition, metallic vapour is sometimes produced, and this gives rise to an arc between the brush tip and the commutator segment which has just left it. Both these sources of trouble are removed when carbon brushes are used. In addition, there is a definite contact-resistance between a carbon brush and the commutator segment on which it rests, and this resistance increases as the commutator segment is withdrawn from under the brush. The effect of this is, that the current in the armature coil short-circuited by the brush is first reduced to zero, and then reversed, without any help from a reversing field. The method of commutation with movable brushes may be compared with the method of stopping a locomotive by reversing the engines, while the use of fixed carbon brushes for commutation may be compared with the use of a brake. In spite of the success already obtained in designing dynamos which run sparklessly with fixed brushes, it must be admitted that there is probably still great room for improvement. The phenomena attending commutation have so far been but scantily investigated; Arnold and Mie have indeed worked out the theory of commutation when the breadth of the carbon brush is equal to that of a commutator segment, but then the brush is generally much wider than this, not uncommonly covering from three to five commutator segments. Then, again, we at present have many grades of carbon which can be used for brushes, and we need data to assist in the choice of the most suitable kind. A first step in this direction has been made by Dr. Max Kahn, who has published a short treatise on the contact-resistance of carbon brushes.* He finds that the resistance depends on a number of factors. First of all, it is different for different sorts of carbon. It varies with the mechanical pressure between the brush and the commutator, and also with the velocity of the commutator; an increased velocity at first produces an increased resistance, but if the velocity becomes very great the resistance once more diminishes. The most important factor, however, is the current density. The contact-resistance appears to comprise two parts, one being constant, while the other is inversely proportional to the current density. It is significant to note that the resistance of the electric arc is of a similar character.

* *Der Übergangswiderstand von Kohlenbürsten*, von Dr.-Ing. Max Kahn. (1902. Stuttgart: Ferdinand Enke.)

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THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C., Chemical Engineer and Consulting Chemist, Manchester.

The Mortar and its Technical Equivalents.

IN order to produce chemical reactions, it is necessary that the reacting substances shall be brought into intimate contact. Liquid substances may be made to react without preliminary mechanical treatment; but where we have to deal with solids, it is well known that the more finely they are powdered, and the more intimately they are mixed, the easier it will be to obtain the required reaction. In the laboratory we may use a hammer in order to break up large pieces of mineral matter; we may then put the smaller pieces into an iron or porcelain mortar and powder them finer, or we may pass them into an agate mortar and grind them there to the finest powder obtainable. It will be noticed that in working on a small scale we are restricted to the force which our arms or wrists can exert, aided as far as possible by leverage, as in the case of using a hammer with a longer or shorter handle. But in working on a large scale, obtaining our power from an engine, the force which we can exert is almost unlimited; it naturally follows that we need not adhere to the means which are at our disposal in the laboratory, but may adopt constructions in which we use the greater force at our command.

Thus, in breaking up large stones into smaller fragments, we may use the forces which are obtained by a cutting or crushing motion. Fig. 21 represents a stone breaker in which the jaw A is made to move backwards and forwards in a horizontal direction against a fixed plate or wedge, so that any large pieces of ore which are placed between these are crushed into smaller pieces. The width between the two crushing parts may be regulated so as to produce larger or smaller fragments. The same effect may be produced by passing the large pieces of ore through grooved crushing rollers. Stone-breaking machines are made in different sizes, according to the hardness of material and the quantity to be dealt with; the power required varies accordingly —from half a horse-power to twelve horse-power and more.

The pieces which we have obtained in the crusher may vary in size: it is practicable to obtain them as small as nuts. The next step is to reduce these nuts to fine powder. This may be done in many different ways. Where a hard ore has to be further reduced in size, an apparatus may be used which resembles a mortar in its appearance and action. If we wish to imitate the pounding action of a mortar on a large scale, we can construct a mortar itself in cast steel; we can further have a heavy pestle of the same material, to which we fix a rod with a short piece at the top projecting at a right angle. If we now have a shaft carrying a curved piece of steel revolving near the pestle in such a manner

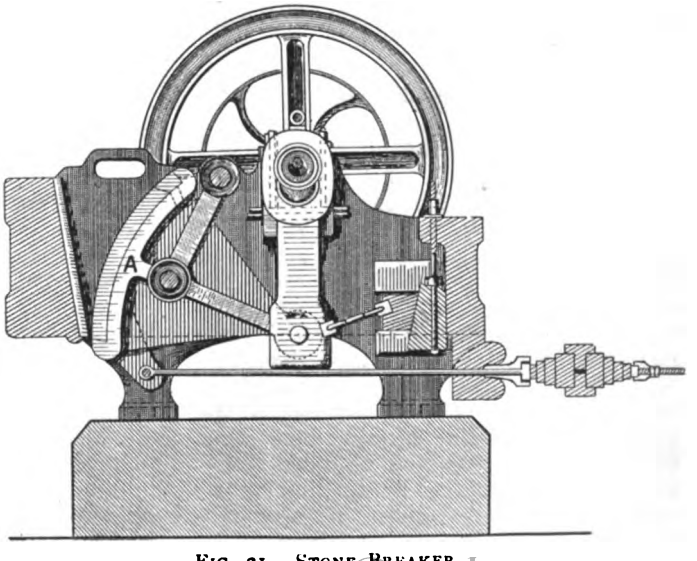

FIG. 21.—STONE BREAKER.

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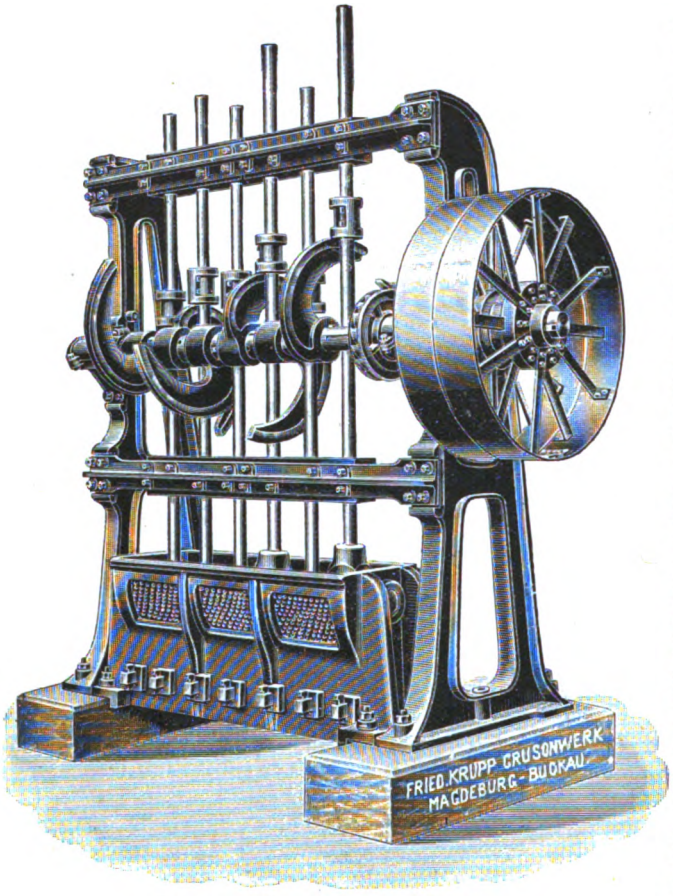

FIG. 22.—ORE-CRUSHING MACHINE.

that the curved piece catches the projection of the pestle at each revolution, it will lift the pestle up, and the latter, falling by its own gravity, will crush the ore. An arrangement of a number of pestles working side by side is largely used in the preparation of ores, and is represented in Fig. 22.

The ore may also be further reduced in fineness by passing it through steel or iron rollers, which may be either grooved or smooth; soft materials, such as coke, may be crushed by being made to pass between two cog wheels, fixed on shafts which revolve in the same or in opposite directions. Where plain or grooved rollers are used, there may be a number of them arranged vertically, in such a manner that the material is first reduced to a certain fineness, then passed through into a second set of rollers below the first set, where it is still further reduced, and so on; so that one may commence with coarse material at the top of the machine and draw from the bottom a product of almost any fineness which may be required.

Where it is necessary to reduce hard ores to the finest state of division, levigation is often used. The substance is finely ground in the dry state, mixed with a large quantity of water, and run through a series of tanks in such a manner that it is left in the first tank for a certain period, then taken into a second tank, and so on. It follows that the coarsest material will settle out in the first tank, somewhat finer material in the second tank, and that in the last tank the very finest material will be obtained. Instead of first grinding the material in the dry state, and then mixing it with water, it may from the start be mixed with water in the grinding mill; the apparatus used for this purpose resembles, in its appearance and principle, a mortar mill, such as can be seen wherever building operations on a large scale are carried on. The mortar mill consists of a plate on which heavy rollers (generally two) revolve. If, instead of a shallow plate, we use a deep trough, the bottom of which, together with the rollers, are made of chilled steel, the sides being built in bricks, we have a machine which in principle represents a wet grinding mill. Mills which are built on the principle of mortar mills are generally termed "edge roller mills"; they may be used for dry as well as wet grinding, in which case the trough we have described is replaced by a shallow pan generally made of cast iron or steel. It is, however, often inadmissible to grind substances in iron, as they become more or less contaminated with that metal. Edge roller mills are, therefore, sometimes made in granite, both as regards the bed and the runners; all parts which are liable to be touched by the material to be ground are arranged in such a manner that no iron or other objectionable material enters into their construction.

Owing to the great variety which we find in the hardness of different substances and in other properties, such as their tendency to cake together, designs of mills are exceedingly numerous. To go back again to the ordinary mortar, we can imagine that, instead of having

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a solid bottom, that part is cut out conically, and in its place is fitted a grooved cone. If the bottom of the hollow part of the mortar from which the cone was cut contains a number of teeth, or is grooved, it follows that if the bottom cone were made to revolve, anything falling between the ridges of the bottom cone and the grooves of the hollow part of the mortar would become crushed. On this principle a number of machines are constructed which are useful for grinding soft materials such as soda-ash and similar chemicals.

Very useful machines for grinding are those which are known by the name of "disintegrators," as it is possible by their help to grind materials of very varied hardness. Fig. 23 represents one of these machines.

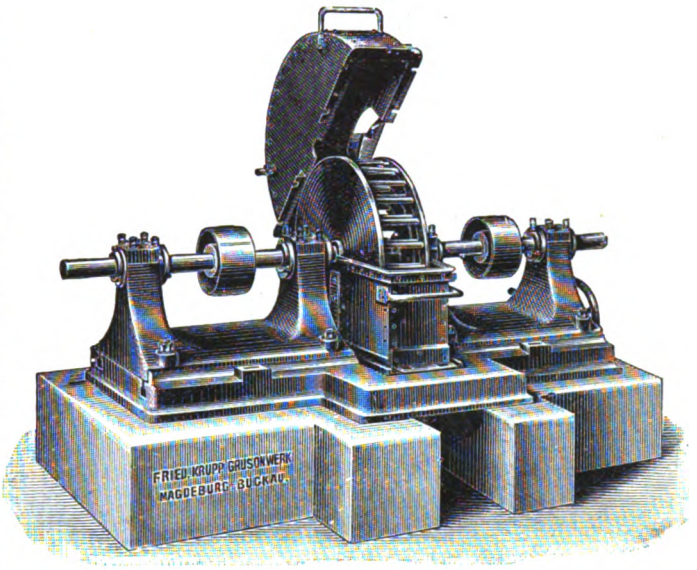

FIG. 23.—DISINTEGRATOR.

The disintegrator consists of a number of steel bars fitted into two or three concentric circles or drums round the driving shaft, and joined to two cages by upright wrought iron discs and rings. The cages are fixed on horizontal shafts, and fit into one another in such a way that the drum of one cage can turn in the circular space between the two drums of the other cage. Pulleys on the shafts are arranged in such a manner that the two cages rotate in opposite directions. The cages are enclosed in a casing of sheet iron which can be easily removed, and with which is connected a hopper for feeding the machine. The materials to be ground are fed into the innermost drum, and are thrown outward by centrifugal force through the space between the bars, which are revolving in opposite directions. The material is thus subjected to a great number of blows, and is ground to a considerable degree of fineness. As the disintegrators revolve at high speeds (a thousand revolutions and more per minute), and as they work on the centrifugal principle, any obstruction which may occur in these machines will produce serious consequences; they therefore require careful attention.

Another construction which is frequently used for grinding materials of moderate hardness is one in which the grinding is effected by the weights of iron rollers. The mill consists of a cylindrical vessel (commonly called a mill barrel) in which are placed a number of solid cast iron rollers. There is a man-hole at the top or sides of the barrel, with an arrangement by which it can be easily opened and closed; through this the material to be ground is charged and ultimately discharged. These mills are either driven from a pulley which is fixed on the centre-shaft, or from gearing working into a spur-wheel which is fixed round the outside of the barrel. Instead of using rollers for grinding, a number of cannon balls may be used for the same purpose. Both this mill and the one which we are going to describe next may be used, not only for grinding materials dry, but also in the wet state; it is possible to obtain a very finely ground mass by their aid. Instead of a cylindrical barrel, a spherical vessel is frequently used, which rotates at an angle to the horizontal, as shown in Fig. 24. The grinding in this mill is effected with the aid of cannon balls.

Where an extreme degree of fineness is required, and where it is not practicable to use iron or steel machinery, the well-known mills which have been used for many years for grinding corn are still applied. In these mills the material is ground between two circular stone slabs into which grooves are cut, the two slabs rotating against each other.

We have only enumerated a few of the many designs which are on the market. In choosing a mill for a special purpose, it is essential to consider the particular requirements for which it is wanted. Thus if we can set aside a mill for a special purpose, so as to always grind the same material in it, it is not very essential that we should be able to take

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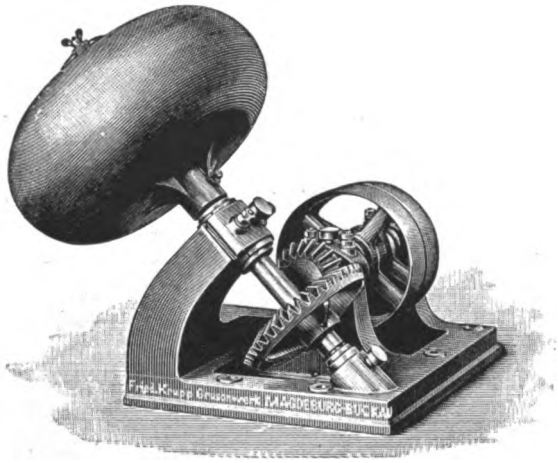

FIG. 24.—MILL FOR GRINDING BY AID OF CANNON BALLS.

the mill quickly to pieces for cleaning purposes. If, however, a mill is required to grind several kinds of materials successively, so that it has to be carefully cleaned out between changes, we shall have to lay particular stress on choosing one constructed so as to allow the cleaning to be done in the shortest possible time. In all cases it is necessary to make sure that any broken parts can be easily replaced; it will be even necessary to consider local conditions, as in some mills, such as the "stamps," the noise produced is such that they would be considered a nuisance in densely populated parts.

We have previously laid great stress on the importance, to the chemical engineer, of a sound theoretical training. We now must point out the importance of practical experience. Although every maker of grinding machinery will undertake to work samples through his machines, and recommend machines amongst those which he makes which best meet the requirements of the case, it is not always (particularly in new installations) possible to obtain sufficient material for the purpose. To get a thorough knowledge of the machines which are used in chemical technology, it is necessary that one should see them at work, and every opportunity should be taken of obtaining such practical demonstration. There is unfortunately no college or technical school at which machinery of this kind can be seen working on a sufficiently large scale to be of any great value. Some day we may have a college which will be conducted on lines enabling the student to work out processes on a large scale; but until such is the case we venture to make a suggestion which, if carried out, would assist the student very much in his studies, and enable such experimental schools as we have mentioned to be built at a small outlay, or the present schools to become more efficient at greatly reduced cost. Many lectures are at present illustrated by means of pictures thrown on the screen by a magic lantern. If views of machinery in motion, taken by means of a kinematograph, were used, they would give the student a practical demonstration which should be of great value. It would be only necessary to demonstrate the principle of the machinery by means of small crude models, and show the working on a large scale by the moving picture.

The material, after leaving the grinding

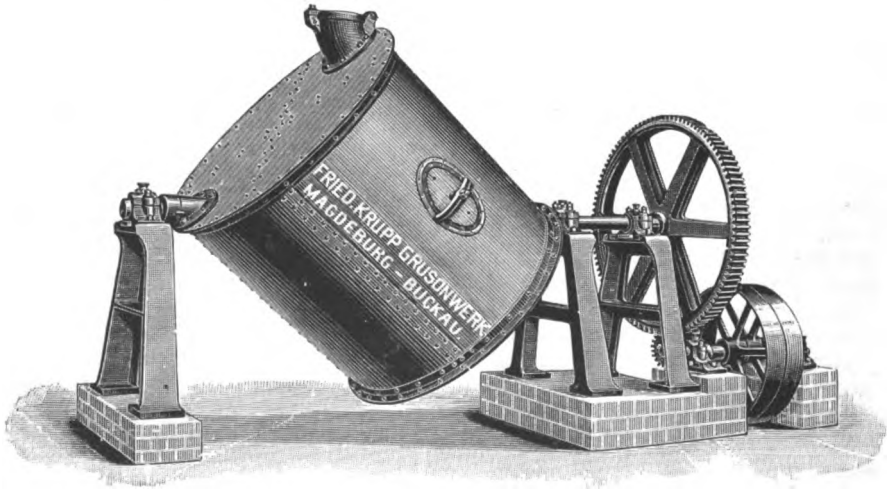

FIG. 25.—MACHINE FOR MIXING DRY MATERIALS.

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mills, is not of uniform fineness. It is therefore necessary to separate the finest part from the grit; for this purpose sieves are used, made either in metal wire or in silk mesh. This mesh, in the case of metal, is classified according to the number of openings to the inch, and is accordingly given as 20, 40, 60, 80, or 90 mesh. Everyone is familiar with the ordinary sieve, which consists of a shallow drum into which a sheet of copper, brass, or silk mesh is fitted; this may be used where not very large quantities have to be dealt with. A number of such sieves may be placed on a table and suitably fastened to it, whilst the table is made to revolve at a fair speed in such a manner that it occasionally receives a knock which throws it violently up. Where large quantities have to be sieved, an oblong sieve may be used, arranged in such a manner that it has a quick horizontal oscillating movement, and occasionally receives a knock throwing it up in a vertical direction. As the material moves along in the sieve, the finest part will fall through into a box underneath, and the coarser part can be made to travel into another receptacle from which it is taken back to the mill to be ground finer. Another construction is one in which the mesh is placed outside the frame, and forms either a circular or an octagonal long tube which is made to revolve by means of a centre shaft.

Besides being used for grinding materials, the mortar is frequently used in the laboratory for mixing ground substances together, or for incorporating finely ground solids with liquids. Similar operations frequently have to be carried out on a large scale. A convenient arrangement to mix dry materials is shown in Fig. 25; this consists of an iron drum fixed obliquely on a horizontal axle. Through the rotation of the drum the various materials inside are thrown against one another, and in a short time they become thoroughly mixed. When it is desired to incorporate liquids and finely ground solids, many of the mills which we have discussed could be used, particularly edge runner and roller mills. In many cases special apparatus designed for the purpose will, however, be found more suitable. One of these is shown in Fig. 26; this consists of a mixing trough in which rotate blades of special construction. A machine of this description may be obtained in different sizes, capable of dealing with small or large quantities.

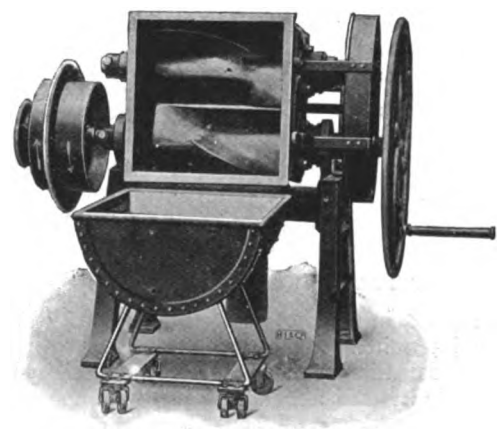

FIG. 26.—MACHINE FOR INCORPORATING LIQUIDS AND FINELY-GROUND SOLIDS.

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THE MANUFACTURE OF SULPHATE OF AMMONIA.

By THOS. HOLGATE, M.I.C.E.

THE ammonia liberated by the distillation of coal and other ligneous materials may be converted into a marketable product in a variety of ways. It may be made into a concentrated solution of ammonia gas freed from pyridine and other tarry matters; it may be liquefied under considerable pressure as anhydrous ammonia for use in refrigerating machinery; or it may be combined with a variety of acids to produce, in the solid form, carbonate, chloride, nitrate or sulphate of ammonia. Of these, the sulphate occupies a foremost place, both in ease of manufacture and in the magnitude of the trade done.

The uses of sulphate of ammonia continue to increase, its value as a manure having been proved by many years of practical working in competition with nitrate of soda. Both of these salts depend upon the nitrogen they contain for their fertilising action. The cheapest form in which nitrogen can be furnished to the soil is by the sulphate of ammonia, and this has the advantage of not being easily washed out by excessive rainfall.

During the year 1904 there were produced in the United Kingdom the following quantities of sulphate of ammonia, 177,000 tons of which were exported, and the balance of 67,500 tons used at home.

	Tons.
In iron works	19,000
Coke and carbonising works and producer gas	32,000
Shale distilling for oil works . .	39,500
Coal-gas works	154,000
	244,500

Modern Forms of Plant.

Various forms of plant are in use for this manufacture, but the intermittent type is steadily giving place to the continuous, which latter varies little in its main features, although the plant made by different makers differs somewhat in important details.

The fundamental parts of a continuous plant are: first, the still; second, the pre-heater, in which the ammoniacal liquor, on its way to the still, receives heat either from the spent liquor or from the gases issuing from the saturator; third, the condenser, and other appliances for utilising the waste gases consisting largely of H_2S, CO_2, and a trace of HCN and other gases; fourth, the lime-mixing and feeding device needed where the "fixed" ammonia is recovered; fifth, the "catch" from the condenser of the "devil" liquor, containing SH_2 in solution, returned by pump to the still; sixth, the saturator, with the complementary acid and mother liquor tanks, sulphate of ammonia draining table, and sulphate of ammonia stores; seventh, receptacles for the ammoniacal liquor to be distilled; eighth, tanks for the removal of solid matter (lime) before allowing the effluent or spent liquor to escape. Each maker develops these details or their combination in his own way, and some of these are described at length in the remarks that follow.

The Chemical Engineering Company employs a still of the form shown in Fig. 1. The upper section, where the "free" ammonia is liberated, consists of a succession of trays like the one shown in section at A. The baffle, having serrated edges, is longitudinal, so that it may be drawn out at the hand-holes for facility of cleaning. It is also placed in such a position that the ammoniacal liquor must pass over it, by reason of the inlet to each tray being immediately opposite the outlet, with the agitated zone of liquor intervening. The liquor, after being denuded of its "free" ammonia, enters the liming chamber, also shown in section. The inlet for lime is at the place where there is the downward flow of liquor, and the mixture flows across the chamber (the contents of which are heated and agitated by steam) to the outlet.

The gas passage from the lower part of the still stands in the centre of the liming chamber, and the gases rising help to heat the lime and liquor. The mixed lime and liquor flow thence through a succession of trays similar in form to A, the lowest tier being shown in section, revealing also the connecting pipe leading to the automatic discharge valve B.

On the opposite side is a vessel C, which acts as a stand for a glass tube level indicator, and parallel therewith is a blow-off pipe acting as a safety jet. The automatic outlet valve consists of a float made of suitable resisting metal, the lowest part of the float acting as a cone valve. When the supply of

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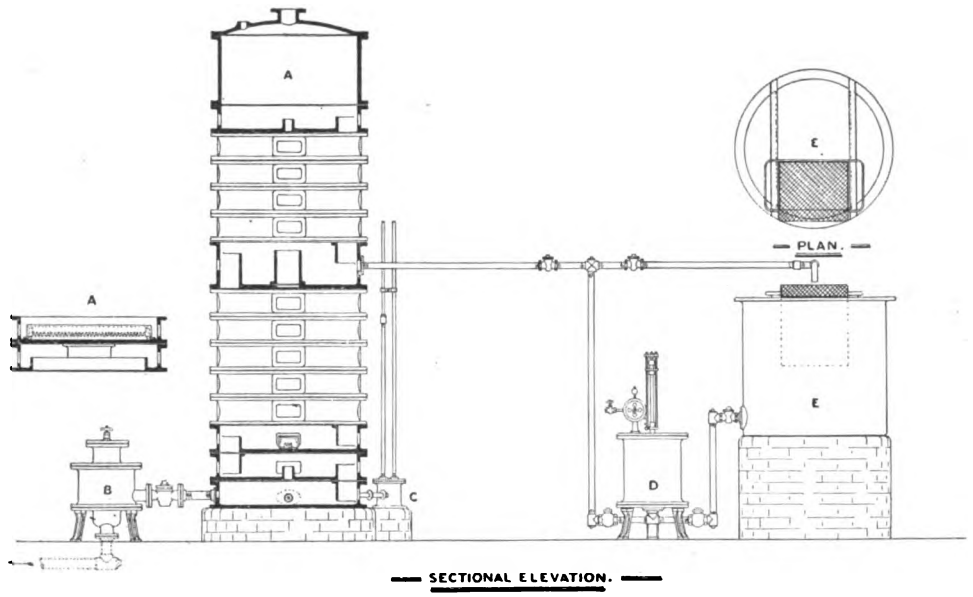

FIG. 1.—WILTON'S CONTINUOUS AMMONIA STILL, WITH LIMING APPARATUS.

liquor ceases, the float valve subsides on to the seat, so that no escape of steam or gases may take place. Of somewhat similar construction is the float valve for the automatic lime feed D. Lime is placed in the basket shown in plan and elevation at E, and a portion of the spent liquor is intermingled therewith. The insoluble portion remains in the basket and is easily removed, whilst the milk of lime passes through a regulating cock and non-return valve into D. As soon as the float therein is raised sufficiently high, it turns on steam automatically at the valve on the left of the float-guide seen above D. The effect of this is to propel the milk of lime through the other non-return valve up the vertical pipe, in such proportion as may be required, into the liming chamber of the still, or back as an overflow to E.

THE SATURATOR.

To make about 1 ton of salt per 24 hours a saturator (Fig. 2) may be employed, arranged for scoop removal. The apparatus is divided essentially into two parts—a circular trough or container for the sulphuric acid, and an elliptically shaped curtain and cracker pipe combined. The distinguishing feature of such an arrangement is the relative absence of strain in the leadwork due to changes of temperature or the effect of weight. The freedom of movement as a whole which is allowed, tends to preserve the shape without tearing at the "burning" or joints.

The cracker pipe is shown with the perforations for the passage of the steam, NH_3, H_2S and CO_2 gases; and the sloping bottom of the container facilitates the fall of the salt to the space in front, where the floor is of double thickness sheet-lead, to resist the wear and tear of the scoop. For an output of 10 tons and upwards per diem it is desirable to obviate the manual labour of removal by scoop; and whilst in some systems of working the saturator is provided with a "well" and discharge valve at the bottom thereof, in others the "well" is fitted for top discharge. In the latter arrangement the lifting of the salt is on Maltster's system effected by compressed air, and in Wilton's system by steam acting through a discharger as shown in Fig. 3. The steam-pipe terminates in a jet upturned and entering the perforated foot, and is under control by a valve just above the saturator dome. When a sufficient quantity of salt has accumulated round the foot, the attendant allows steam to impinge on it, with the result that it is forced up the vertical tube into the draining table. Thence the surplus liquid—the acid and mother liquor—flow by gravity into the rectangular lead-lined vessel, shown in elevation, whence, with added sulphuric acid, it flows down the inclined pipe into the saturator. The mother liquor tank is fixed at such a height as to give a proper working level in the saturator, which, as will be seen, is of the closed type. It is built of a timber framework lined with

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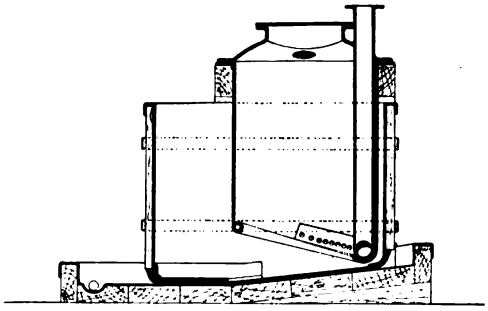
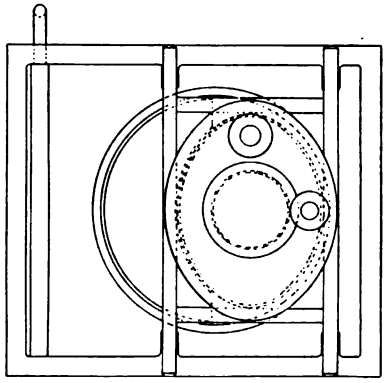


Vertical Section.



Plan.

FIG. 2.—WILTON'S SATURATOR, WITH INDEPENDENT CONTAINER.

chemical sheet lead. At the side is a large manhole for inspection and repairs, whilst through the dome passes the gas inlet pipe in two divisions. This is for the purpose of giving uniform distribution to the circular cracker pipe within. The outlet gas pipe enters a spray separator of larger capacity than the cross section of the pipe, which, reducing the velocity of the gases and providing perforated lead trays, facilitates the deposition of the acid spray that might otherwise be carried forward and cause mischief to iron pipes. It will be noticed that the weight of the various pipes is carried by the iron and timber framework so as to relieve the leadwork.

A form of saturator largely employed is the one shown in Fig. 5, and known as the piano-shape. This is often built of plate lead 1 inch thick without external framework, but the view given represents Standfast's patent construction, which is electrically welded. It is composed of a lead body made of sheets $\frac{1}{4}$ inch thick, all the joints of which are welded electrically. This body is contained within a framework of steel tees and angles, made in

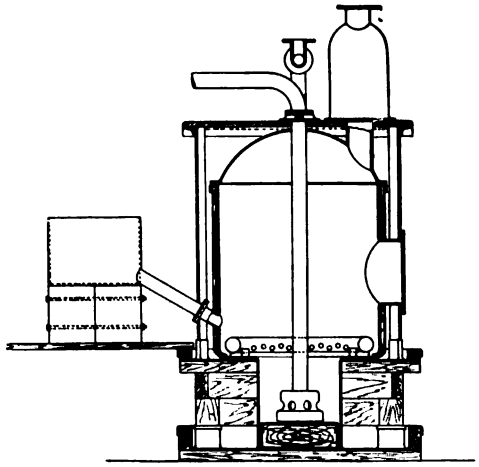


FIG. 3.—SECTION OF SATURATOR, WITH WILTON'S DISCHARGER.

sections, arranged so that each can be removed, in order to get at any portion of the lead body which may require attention. For the purpose of resisting strains, the leadwork is strengthened and made more homogeneous by electric welding. The temperature of the electric arc used for the fusion of lead is kept below that used for iron and steel, but still sufficiently high to cause each lead sheet

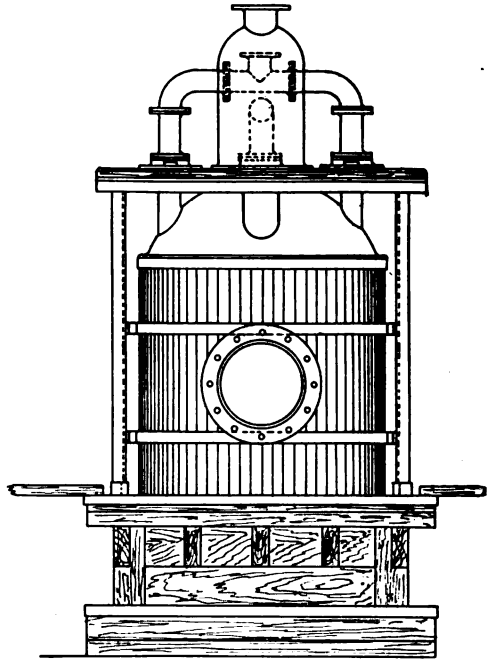


FIG. 4.—ELEVATION OF SATURATOR, WITH WILTON'S DISCHARGER.

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to unite with its neighbour throughout its entire thickness. As there is no flame of an oxidising character, the lead remains perfectly clean under the operation, and a fracture of the lead after welding shows that the two pieces have been entirely incorporated. The firm for whom Mr. Standfast is manager, and who are large manufacturers of chemicals in the South of England, have used the detachable framework structure for several years, and have recently combined therewith the electric welding of the lead with very satisfactory results. The electric welding was done at the works of the Steel Barrel Co., Ltd., Uxbridge, who not only make these saturators, but electrically welded steel barrels. The illustration, Fig. 5, is of a saturator to make 2 tons of sulphate per day. It is prepared for scoop removal, the floor of the saturator in front of the curtain being double thickness of lead to resist wear. The gas inlet to the cracker pipe is shown entering the back, the manhole, acid funnel and gas-outlet being shown on the top; the slope of

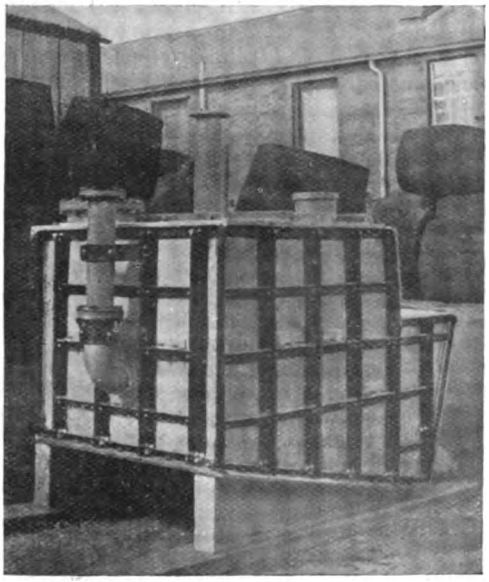

FIG. 5.—STANDFAST'S SATURATOR.

the floor, and the method of constructing the framework, are also clearly indicated.

LEAD BURNING.

The important part which leadwork plays in a sulphate of ammonia plant requires that all lead which comes in contact with boiling acid should be of chemical quality, that is, free from impurities; and also that all seams should be well burned together. The ordinary method of uniting lead sheets together is by fusion with a flame of hydrogen burning in air; but experience shows that such joints are very readily acted upon by hot acid, and also are mechanically weak in resisting the strains set up by changes of temperature, from hot whilst at work to cold when at rest. The union is frequently only superficial, and there is danger of tarnishing the cleaned surface at the moment of burning by the action of the flame, which may contain arsenic and sulphur from the zinc and acid used in the generation of the hydrogen gas.

Mr. Robertson, Chemist of the Government powder works at Waltham Abbey, has tested samples of zinc by the Marsh-Berzelius process, and found the following percentages of arsenic:—

1. Samples from Ash and Lacey, 0·00008 to 0·00015 per cent.
2. One sample, marked G. V. Giesches Erben, 0·0008 per cent.
3. One sample, Brunner Mond & Co., (electrolytic), 0·00008 per cent.

Samples of sulphuric acid yielded percentages of arsenic as follows:—

(*a*) Denitrated, not concentrated, 0·00022 per cent.

(*b*) Concentrated from the Kessler evaporator, 0·00022 per cent.

(*c*) Chapman and Messel's acid, 0·00011 per cent.

Not only is the impurity contained in the hydrogen gas injurious to the "burning" of the lead, but it is poisonous to the workmen, especially if they are in close workshops or inside small vessels such as saturators. Dr. G. Lunge has studied the effect of AsH_3 (arsine or arseniuretted hydrogen) upon lead burners, and says that, taking 0·0005 per cent. of arsenic in the zinc and 0·00022 per cent. in the acid, a week's work in the soldering shop at Edmondsey would produce 180 c.c. of AsH_3, forming on combustion 0·845 grm. of As_2O_3 or 0·141 gram per day. This amount of arsenic trioxide is small, but would easily be increased if a zinc similar to sample 2 were used; but the danger due to smaller quantity is not to be disregarded, nor is that due to accumulations of arsenical dust.

Arsine itself is much more poisonous than the As_2O_3; the escape of the impure hydrogen through faulty tubing, which is usually of indiarubber, or from connections or leaks in the apparatus, should be carefully guarded against. Robertson recommends that the gas before burning should be passed through a 5 per cent. solution of permanganate, or

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of chromic acid in sulphuric acid, to remove the arsine; copper sulphate solution, previously used for this purpose, has been found to be ineffectual. Other methods of avoiding contamination have been suggested, but the one which has been found best in practice is to use a blowpipe fed with oxygen and coal gas. If ordinary coal gas is not available, then cylinders of compressed hydrogen, or better, compressed coal gas or acetylene may be used. Not only does the use of oxygen overcome the difficulties already enumerated, but it furnishes a flame of higher temperature, which is more efficacious and rapid in the fusion of the lead sheets.

The compressed oxygen, which is at 120 atmospheres pressure, is reduced to one atmosphere by a regulator fixed on the cylinder. At this pressure it enters the blowpipe, which is on the injector principle, *i.e.*, the high velocity of the issuing oxygen induces the flow of the coal gas admitted concentrically. Each gas is controlled by a separate cock, and the size of jet is determined by the thickness of the sheets to be united. The flame has two cones: the inner, which is short and white, and the outer, which is long and reddish brown. The lead is rapidly melted by touching it with the inner cone of the flame, and the metal surfaces remain clean and free from the discolouration usual with ordinary burning.

The temperature reached with coal gas and oxygen may be 4000° Fahr.; with hydrogen in lieu of coal gas about 6000° Fahr.; with acetylene 7000° Fahr.; and with the electric arc 7200° Fahr. In some cases, to avoid an oxidising flame, it may be necessary to alter the proportions of hydrogen or acetylene and the oxygen, with a reduction of the temperatures to 4200° Fahr. and 5700° Fahr. respectively. It is quite clear from these figures that the requirements of good lead burning may now be met, for if electric welding is beyond reach then the oxygen-fed flames may be employed.

Utilising the Sulphur, etc., in the Waste Gases.

The ammonia contained in the gases liberated in the still having been absorbed by the sulphuric acid in the saturator, and the salt thus formed removed therefrom in the manner already described, the unabsorbed gases (H_2O, CO_2 and H_2S) are passed into the sulphur recovery portion of the plant. *En route* to this section it is possible to utilise the heat that they contain for the purification of ammoniacal liquor (as referred to in Technics, Vol. II., page 420), or if not utilised, the heat must be got rid of by cooling the gases in an air or water condenser. At 60° Fahr. the greater part of the moisture will have been removed, and the comparatively dry gas may be passed into an oxide of iron purifier to absorb the H_2S, leaving the CO_2 to pass into the atmosphere; or it may be partially consumed in a Claus kiln, in which case the reaction taking place is $2H_2S + O_2 = 2H_2O + S_2$, but this is accompanied by another and undesirable reaction, *viz.*, $2H_2S + 3O_2 = 2H_2O + 2SO_2$. The sulphur produced by the first reaction is deposited as "flowers" of sulphur in the chambers following the kiln, and the sulphurous acid gas produced by the second action is removed from the gases after they have left the depositing chambers by washing with water in a limestone tower.

Where the output is sufficiently large the best method is to convert the H_2S wholly into SO_2, and pass the same with nitrous gases into the chambers of a sulphuric acid plant, thereby producing the acid required in the sulphate of ammonia manufacture.

General Expenditure.

The chief items of cost are (*a*) labour, (*b*) generation of steam for heating the liquor, (*c*) sulphuric acid, (*d*) lime, (*e*) packing and delivery of the sulphate, (*f*) capital charges. Of these, we can only refer to the two important ones viewed from a technical standpoint, namely the chemicals used.

Good grey sulphate of ammonia of merchantable quality can be produced from sulphuric acid made from spent oxide of iron, which in many localities is cheaper than that made from brimstone. Where acid made from pyrites is much cheaper than that made from oxide, it may be satisfactorily used if it first be freed from arsenic; this process may be carried out either at the vitriol works or at

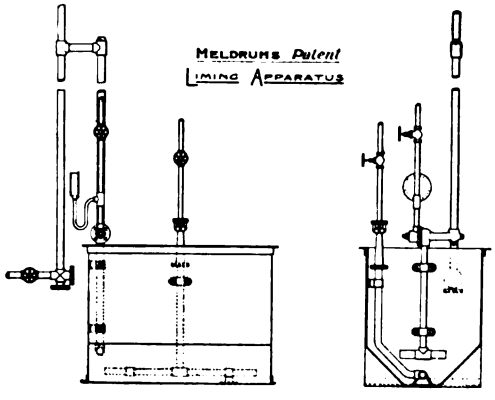

Fig. 6.—Meldrum's Liming Apparatus.

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the sulphate of ammonia works. In the last-named case, the sulphuretted hydrogen in the gases issuing from the saturator may be used to throw down the arsenic in the vitriol in the form of sulphide of arsenic, and this may be removed by filtration.

As to lime, the amount required is determined by the proportion of ammonia present in the liquor as chloride, thiosulphate, sulphate and other fixed salts; and as an excess is always required in practice, the extent of that excess must be checked by frequent analyses of the effluent liquor. As the ammoniacal liquor is flowing through the still continuously, it is desirable that the lime should mingle therewith in definite proportion and also in a constant stream. In addition to the method shown in the earlier part of this article, there is one in which the lime-feed is controlled by a steam injector. The apparatus (see Fig. 6) consists of a tank with steam jet agitator and air distributing pipe, together with an injector provided with cleaning plugs and removable nozzle. The mixing tank is made with a V-shaped lower part, near the bottom of which runs the air-distributing pipe, so that agitation is maintained and the tendency of the heavier particles of lime to settle is counteracted by the outrush of air from the perforations in the pipe.

DETERMINATION OF SILICON IN IRON AND STEEL.

By FRED IBBOTSON, B.Sc.

WHEN steel or pig iron is dissolved in any one of the mineral acids or in any mixture of them, the silicon is converted into silicic acid and it is then only necessary to convert this into silica by dehydration.

The results obtained by either of the following processes will be found to be practically identical—

Method I.—In the case of steel, weigh off five grams of the drillings into a wide beaker of about 500 c.c. capacity and add about 60 c.c. of the following acid mixture, replacing the cover-glass at once—

Sulphuric acid (1·84) . . .	250 c.c.
Nitric acid (1·42)	400 c.c.
Water	1000 c.c.

Place the beaker over a heated sand bath, or preferably on a heated iron plate, and allow the contents to boil down as quickly as possible. Before all the nitric acid has been expelled, a thick crust of ferric sulphate will have separated, but the heating must be continued further until copious fumes of sulphur trioxide escape. The silicic acid has then become completely dehydrated, and the mass may be extracted. This should be done at once by the careful addition to the hot mass of about 200 c.c. of warm water. The mixture is then heated to boiling, about 20 c.c. of strong hydrochloric acid being added to effect complete solution of the iron. The insoluble silica is then filtered through ashless paper or pulp, washed well with dilute hydrochloric acid until the washings are free from iron, and finally ignited,

$$SiO_2 \times 0{\cdot}4667 = \text{silicon.}$$

Method II.—Dissolve five grams of steel drillings in 40 c.c. of concentrated hydrochloric acid and set the solution to evaporate. When the mass reaches the pasty condition, remove the cover glass, and conduct the subsequent evaporation cautiously in order to avoid loss by projection. The dry yellowish residue is then further heated until all traces of yellowness have disappeared, and a red or pink colour has taken its place. By this treatment the silicic acid is dehydrated; after being allowed to cool, the mass may be extracted with about 20 c.c. of strong hydrochloric acid followed by ten times as much hot water. After boiling for a minute, filter, wash as in Method I., and complete by weighing as silica.

In both methods ignition is conducted in a weighed platinum crucible, and the residue should be perfectly white. The purity of the silica is tested by adding one drop of sulphuric acid and a few drops of aqueous hydrofluoric acid. The excess of the latter, and the silicon tetrafluoride formed, are then expelled by gentle evaporation, and the sulphuric acid at a higher temperature. The last traces of this acid can only be removed by heating over the blow-pipe or in a muffle at a bright red heat. The loss in weight by this treatment represents the silica.

In the case of pig irons (grey and mottled), one gram of the sample only is required, and Method I. is recommended. The final residue contains graphite as well as silica; and the complete removal of this by ignition to carbon dioxide requires much more time. The treatment of the final product with hydrofluoric and sulphuric acids is strongly recommended in the case of graphitic irons.

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ELECTRICITY FROM TOWNS' REFUSE.

By WALTER P. ADAMS, M.I.E.E., A.K.C.

(Concluded.)

WE have seen that one and a-half pounds of steam per pound of refuse ought to be, and is in some cases, obtained in a well-designed destructor; and thus, under favourable conditions, 84 units per ton of refuse ought to be obtained. This does not, by any means, represent the maximum obtainable in the future destructor. Two pounds of water per pound of refuse will certainly be obtained regularly under good conditions; this, with the Hackney water consumption, which represents good modern practice, gives 128 units per ton. In one Lancashire town I am informed that as much as three pounds of steam is regularly evaporated per pound of refuse, but I have not had the opportunity of verifying this yet.

Now let us consider what is actually being accomplished at the present time. I have recently been able to make a careful investigation at the London works, and a few diagrams will help to demonstrate my conclusions.

Fig. 5 is a diagram of the output of the Stepney Electricity Works during 1903. The shaded portion represents units generated by coal, and the upper part the balance generated by refuse; these have been carefully measured and ascertained, and the result over the year is 32 units per ton. The arrangements for utilising the steam generated from the Stepney refuse are far from satisfactory, and for every unit generated from the refuse-steam no less than 72·5 pounds of water were evaporated. I must not enter too fully into details, but with improved arrangements 50 units per ton ought readily to be obtained.

In Fig. 6 we have the Fulham load diagram for year ending May, 1903. Owing to the neglect of water measurement, the units generated from coal had to be calculated. This, however, has been done with care, and the refuse value is approximately correct: for the year, 27·8 units were generated per ton of refuse burnt. Fig. 7 shows, however, that the load on the station is not large enough, on the morning and afternoon shifts, to utilise the full value of the refuse which is burnt steadily throughout twenty-four hours; and only on the last shift, or peak load, is the value of the refuse obtained. This diagram is valuable as demonstrating that some 70 units per ton might be obtained throughout the day, instead of 45·3, if the load on the first two shifts rose to 400 kilowatts. I have drawn out a number of day load diagrams for Fulham, some giving better and some worse results; that reproduced, may be fairly taken as an average. In summer, with a smaller load, considerably less than an

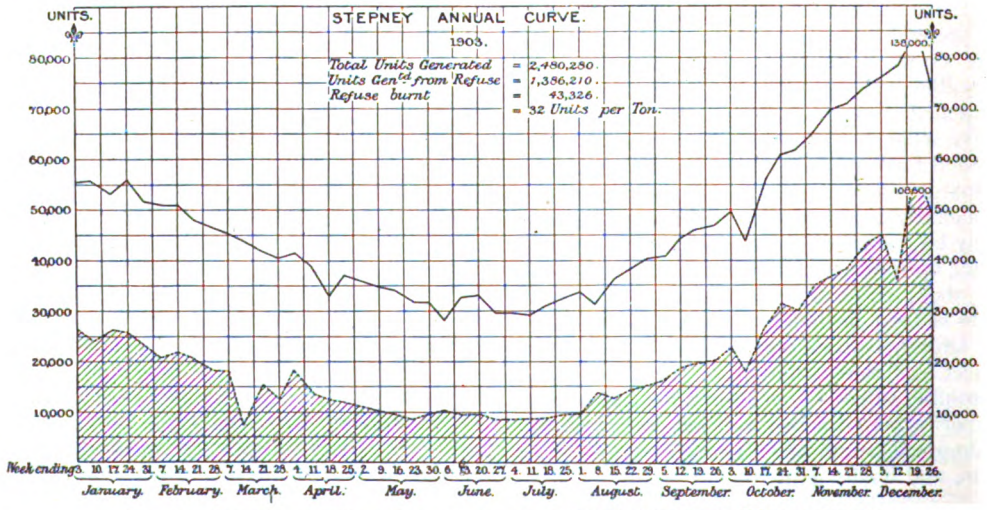

FIG. 5.—CURVES SHOWING OUTPUT OF STEPNEY ELECTRICITY WORKS (1903).

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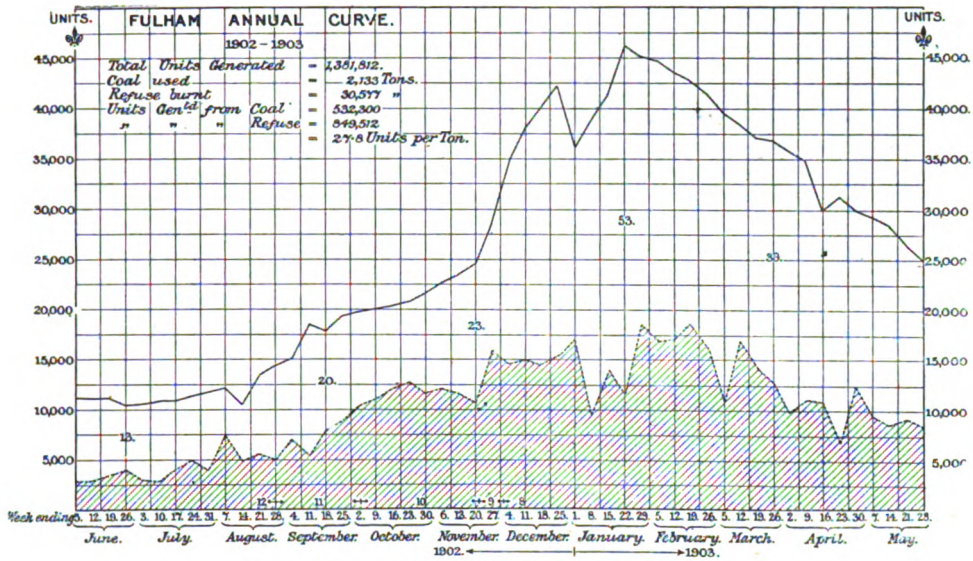

FIG. 6.—FULHAM LOAD DIAGRAM, FOR YEAR 1903.

average of 48 units per ton over twenty-four hours is obtained, so it will be readily understood how the low year's average of 27·8 results. When the load on the works is large enough, and the water consumption is reduced to a reasonable figure, 70 units per ton should ultimately be obtained.

I have already spoken of the economical nature of the electrical generating plant at Hackney, so here good results might reasonably be expected; and if we confined our attention to Fig. 8, giving the load on the works for the year ending May, 1903, the figure of 41 units per ton would be disappointing; but with the aid of a day load diagram (Fig. 9), this, however, is readily explained. It will be seen, as at Fulham, the load on the generators is not sufficient to get the full value from the refuse, except on the last shift; it is, however, sufficient for the rest of the day, and only on the peak is coal burned. The value of the refuse on the peak is over 100 units per ton, and if the load were big enough, there is no reason why 100 units per ton should not be obtainable throughout the day, as the refuse is burnt at a uniform rate. Fig. 10 is of specia interest, as on this day no coal was burnt, and again the figure of about 100 units per ton was obtained; in several other diagrams I have drawn, similar results are obtained. There is, however, a deduction to be made to place them on the same level as the Fulham and Stepney figures, as the blast is driven at Hackney by electricity, and at Fulham by steam jet; this will bring the figure to about 90. In summer the refuse

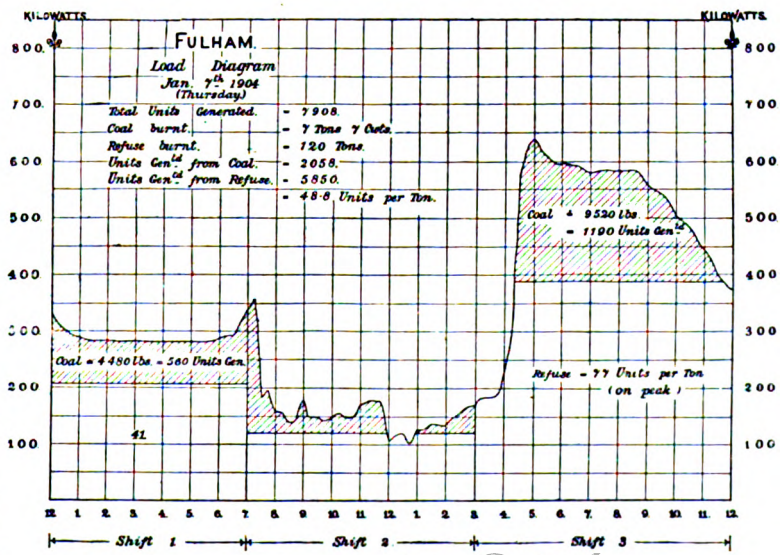
KILOWATTS
FULHAM.
Load Diagram
Jan. 7th 1904
(Thursday)
Total Units Generated. = 7908.
Coal burnt. = 7 Tons 7 Cwts.
Refuse burnt. = 120 Tons.
Units Gen.d from Coal. = 2058.
Units Gen.d from Refuse. = 5850.
= 48·8 Units per Ton.
Coal = 9520 lbs.
= 1190 Units Gen.d
Coal = 4480 lbs. = 560 Units Gen.
Refuse = 77 Units per Ton.
(on peak)
41.
Shift 1 Shift 2 Shift 3

FIG. 7.—FULHAM LOAD DIAGRAM FOR ONE DAY.

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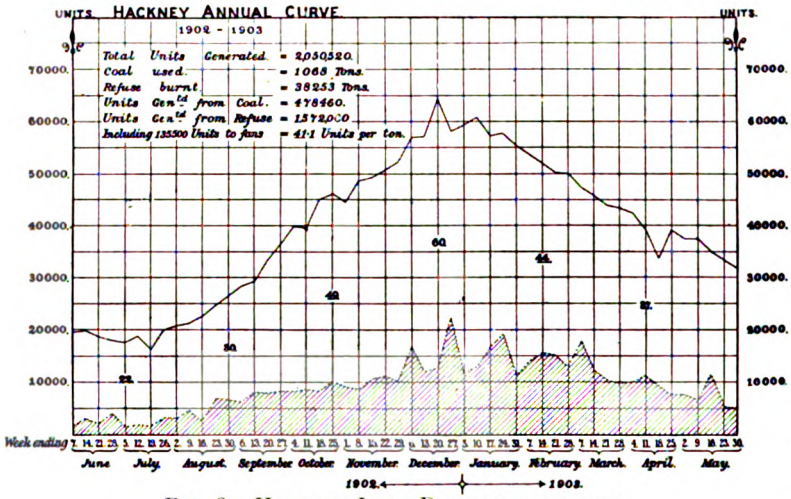

FIG. 8.—HACKNEY LOAD DIAGRAM, 1902–1903.

is of poor quality; but, making allowance for this, 80 units per ton ought to be obtained all the year round when the load is large enough.

It will be observed, in endeavouring to arrive at the ultimate value of the refuse, I have used the expression "ought to be obtained." It is just here that the efficiency of the management comes in, and the poorness of the results obtained in some combined works is largely due to the personal element.

The plant at Woolwich is only recently completed, but from information to hand I look for better results even than those being obtained at Hackney.

The results obtained at Partick are also worthy of note; some 60 units per ton of refuse burnt have been recently obtained over several months, and this with the plant working non-condensing, and taking some 55 pounds of water per unit generated.

The progress that has been made of recent years is remarkable. Three years ago 30 or 40 units per ton were considered the best possible practice, and only recently have such figures as 50 and 60 units per ton been claimed in one or two cases. Until the reading of my paper on the Combination of Electricity Works and Dust Destructors, before the Institution of Electrical Engineers in December last, such a figure as 100 units per ton seems never to have been dreamed of, and in all my close investigations on the subject, extending over three years, such a figure was never met with.

In conclusion, the financial aspect of this question may fittingly receive a brief notice. The most important consideration is the fuel value of the refuse, but besides this, when a refuse destructor is combined with an electricity works, there should be savings in labour and management costs, and some saving in capital expenditure, with its attendant reduction in the annual capital charges.

Dealing with the fuel-value of the refuse in

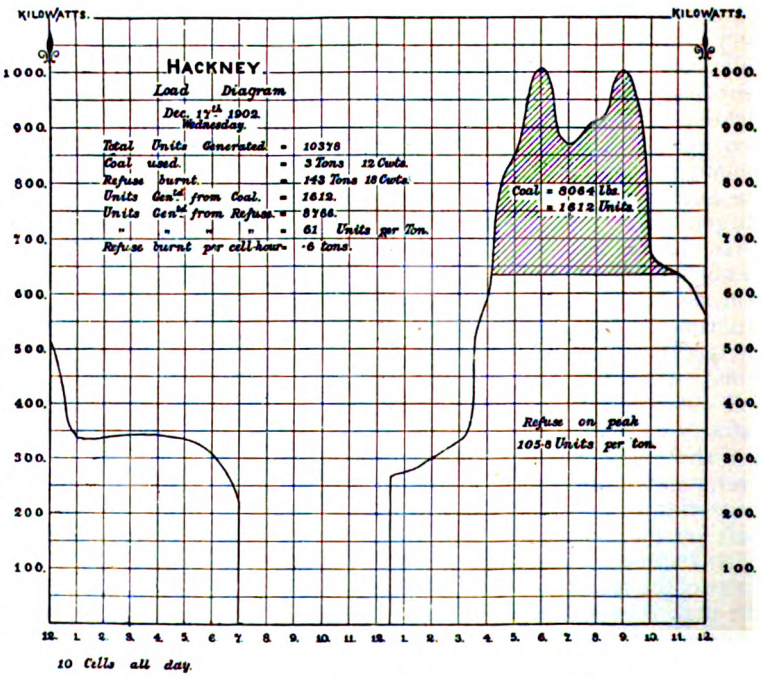

FIG. 9.—HACKNEY LOAD DIAGRAM FOR ONE DAY.

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TABLE V.

Town.	Tons of Refuse Burnt in One Year.	Units per Ton now obtained.	Units per Ton Obtainable when all Refuse is Burnt Usefully. (Engineer's Estimate.)	Coal Cost in Pence per Unit Generated from Coal.	Fuel Value of Refuse, Year ending March, 1903.		Fuel Value when all Refuse is Burnt Usefully.	
					Total.	Pence per Ton.	Total.	Pence per Ton.
					£		£	
Shoreditch .	25,729	31	38	1·04	3052	28·5	4320	40
Stepney . .	41,250	40	40	0·8	2035	11·8	5500	32
Fulham . .	30,200	45	52	0·64	1817	14·4	5000	33·4
Hackney . .	34,006	45	64	0·39	2272	16	4000	25·3
Shipley . .	6,525	40	40	0·41	406	15	444	16·4
Partick . .	13,500	50	67	0·39	470	8·3	812	14·5
Gloucester .	7,800	—	56	0·78	—	—	1465	44

a combined works, it is necessary to ascertain the probable coal cost where the electricity works run on coal only. It should not be a difficult matter to ascertain this in practice, as the works, at intervals, could be run for a week on coal only, and the value ascertained. In one or two cases direct information is to hand, notably from Hackney and Stepney; but at Fulham and Shoreditch it can only be estimated. In a few provincial towns, also, trustworthy data are available. This information is given in Table V.

In column 4 the somewhat modest estimates of the engineers have been taken. These figures ought most certainly to be exceeded, and the figures I have named in the earlier part of my article obtained; in such event the fuel-value of the refuse would be proportionately increased.

Where the cost of coal is high, it is probable that the fuel-value of the refuse is considerable, and its development well worth while. This is notably the case in London. Table I.* shows plainly that London refuse, burnt in a modern destructor, should produce one and a-half pounds of water per pound of refuse, and that 40 pounds of water should suffice to produce a unit. Making good allowances on both heads, 60 units per ton should be obtainable. The coal cost in London uncombined stations is about 0·7d. per unit generated; the fuel-value of the refuse is, therefore, say 3*s.* 4*d.* per ton. There are one and a-quarter million tons of refuse collected annually in the County of London, which has, therefore, a fuel-value of over £200,000 per annum.

These figures speak for themselves; but it is necessary to add, by way of caution, that owing to the variable nature of refuse in different localities, good results cannot always be counted upon, and it is desirable that refuse from each town be carefully examined to ascertain its calorific value before a destructor scheme be decided upon.

Considerable improvement has undoubtedly taken place since the installation of the pioneer combined electricity and destructor works at Shoreditch, and improvement may still be looked for in the direction, firstly, of increased steam-raising value, which

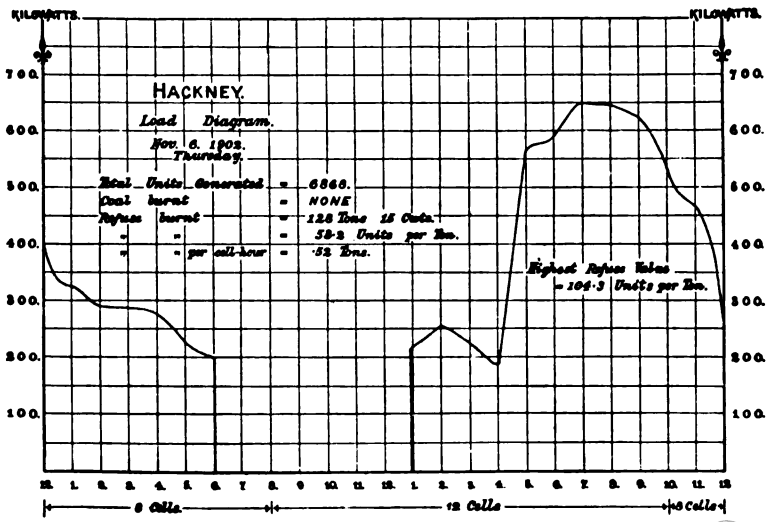

FIG. 10.—HACKNEY LOAD DIAGRAM FOR DAY ON WHICH NO COAL WAS BURNT.

* Technics, Vol. III., No. 15, March, 1905, p. 266.

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means more perfect combustion of the carbon and its utilisation; secondly, a reduction in the quantity of clinker produced, and as a consequence an improvement in its quality, thus rendering it more saleable; and thirdly, in the charging arrangements, by means of which there should be less unpleasantness and dust in its handling.

So far as the efficiency of the destructor is concerned, as a means of destroying refuse, there is little room for improvement; and in a properly worked modern destructor there is practically no nuisance from smell after the refuse has found its way into the furnace. This is a point that is not yet sufficiently appreciated; prejudice dies hard, and the unsatisfactory nature of the early destructors, and the bad odour into which they came, still clings to them. A visit to a modern destructor will soon indicate that there is no unpleasantness resulting from the destructor, but simply from the refuse itself on its way to the furnaces; and it is just here that the need for improvement in the handling of the refuse and charging of the furnaces comes in.

OVER-HEATING OF STORED COAL.

THE storage of coal in bulk, in view of the fire danger that it affords under certain conditions, is a subject of some importance to those engaged in many industries. Cases of spontaneous combustion are of frequent occurrence; generally they are caused by improper methods of storage arising out of the prevailing ignorance on the subject. Warmth or damp in a coal heap sets up a slow process of oxidisation, and heat that cannot escape being evolved, the effect becomes cumulative, both the oxidisation and heat increasing until ignition finally results. Since oxidisation is primarily the cause of the trouble, it is evident that the frequently employed system of placing air tubes in the heap is radically wrong, unless the tubes are constructed of such a size as to permit a constant current of air to pass, sufficient in quantity to carry off the heat evolved. As a rule this is not the case, and such tubes are often too small and arranged upon no proper ventilating system, with the result that, instead of producing a draught, they simply convey air to the interior of the mass and thereby assist oxidisation. Bituminous and semi-bituminous coals are far more liable to heating than those of the anthracite class; and the more damp, volatile matter and sulphur they contain, the greater is the danger of ignition. 4·75 per cent. of water may be taken as the limit that coals of this class should contain, to be safe from undue heating when piled; and should the temperature of the heap attain 140° F., under any conditions, trouble may be anticipated. A simple and effective method of testing the temperature at the centre of a heap consists in ramming an iron rod through to its heart, leaving it there a sufficient time for it to acquire the full heat. Upon withdrawal, an experienced man can tell by his hand if the temperature is dangerous; or a thermometer may be applied to it, the two being enveloped in a handful of waste for a minute or so. The precautions that should be taken against the over-heating of stored coal are simple. It should never be heaped if thoroughly wet, and should be kept in iron or concrete bunkers in a cool place not adjacent to boilers or flues. The pile should never exceed twelve feet in depth, and should be arranged with efficient ventilating spaces round the sides and at the bottom. In the event of combustion or over-heating occurring, the best plan is to turn the coal over thoroughly; pouring water on the top of the heap is of little use, as it may only penetrate sufficiently to make matters worse. If turning over is impossible, and the heart of the pile is suspected to be alight, an effective method is to ram in a good-sized pipe drilled at the end with several holes. When this has penetrated the surrounding coked fuel, a stream of water should be turned on to it, which will speedily result in extinction of the fire.

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EXPANSION CURVES.

By WALTER A. SCOBLE, A.R.C.Sc., Wh.Sc.

IT is frequently necessary to set out a curve having an equation of the form pv^n = constant, and a method of doing this, given in the *American Machinist* for June 21st, 1900, has received much attention since the publication of Mr. Stoddard's pamphlet on "Gas Engine Design," and of a letter from Professor Perry to *Nature*, October 8th, 1903, each of which gives the method. The October issue of TECHNICS contains an article by Mr. H. J. Jones on "Expansion Curves," in which the method is again given, but here it is also somewhat developed.

The problems in connection with expansion curves are: (1): Given the equation, to set out the curve; (2): To find a value of n which will give a curve of the above form most closely approximating to a given expansion curve; and (3): To find the value of n at any particular point on an expansion curve. As I do not wish to include in this article matter which has already been published, I must ask my readers to refer to the October issue of TECHNICS for a detailed explanation and proof of the method under discussion, and they will also find a new problem proposed; (4): Given an indicator diagram, to find the clearance of the cylinder from which the diagram was taken.

Considering our first problem, given the equation, to set out the curve, to the average engineer the method is of interest mainly as a neat construction, as, although it gives the curve with great accuracy, when we consider that probably a point on the curve must have its position calculated, and then, after taking a convenient angle α, β must be calculated from the relation, $1 + \tan\beta = (1 + \tan\alpha)^n$, and set out, we are forced to the conclusion that little is saved as compared with calculating four or five points on the curve in the ordinary way. Anyone having much work of this kind should have a copy of Mr. Stoddard's pamphlet, in which he gives two curves connecting n and $\tan\beta$ for two convenient values of $\tan\alpha$, so that the work necessary to set out a curve is much reduced.

If the curve and the axes of pressure and volume are given, it is generally recognised that the most satisfactory way to obtain n, as required in our second problem, is to plot corresponding values of $\log p$ and $\log v$, and calculate n from the straight line lying most evenly amongst the points. Anyone who has done this for himself must realise that the result obtained is only an approximation, as already stated, but this fact does not appear to be properly realised by many engineers, who will, therefore, not understand the necessity of problem (3). As an example I have plotted $\log p$ and $\log v$ for an actual expansion curve, and taking a mean, straight line between the points, I find $n = \cdot 82$ nearly. Considering only the first two points, and drawing a straight line through them, I find for this part of the expansion curve $n = \cdot 68$ nearly. This shows that n varies as we pass along the curve, and should also suggest a method for finding n corresponding to any point on the expansion curve. Mr. Stoddard applies the construction that we are chiefly concerned with here to find n for any point, but I must refer my readers to his pamphlet, as I do not feel justified in publishing the method, although it is simple, and a direct application of the construction to an expansion curve.

So far the method has not enabled us to tackle any new problem, but many people claim that it will give the clearance when applied to an indicator diagram. This is given in the article on "Expansion Curves," mentioned above, and in it Mr. Jones states "That the clearance can be obtained in the case of gas engines correct to 4 per cent., and for steam engines correct to 7 per cent." If this were so, the method would have a new and very distinct value, as it is very easy to imagine cases in which the clearance volume is not known, and in which it would be at least inconvenient to measure it. However, if we consider the matter carefully, there are several reasons which would appear to make the accuracy of the method doubtful. In the first place, we are no longer dealing with a curve which exactly satisfies an equation of the form $pv^n = c$, as explained above, and we now have two unknowns, the clearance, and n; and bearing these facts in mind, it seems probable that there will be a certain amount of give and take between these two quantities. Again, taking an actual indicator diagram, if we wish to obtain more than two or three points on the required straight line, a must be made small (see Figs. 3 and 4),

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and consequently the point through which the vertical axis of pressure must be erected is given by the intersection of two lines inclined to each other at a small angle. The difficulty in fixing such a point of intersection exactly is well known. It will also be noticed, from the figures given, that the points through which the straight line has to be drawn are close together, and at a comparatively large distance from the required point of intersection. If we remember that the points obtained will not lie exactly on a straight line, and that because of the above facts a small change in direction of the line causes a large change in position of the point of intersection, we find that it is improbable that the clearance can be obtained accurately by this method, especially as, when set out as a fraction of the working volume of the cylinder, it is represented by a very short length.

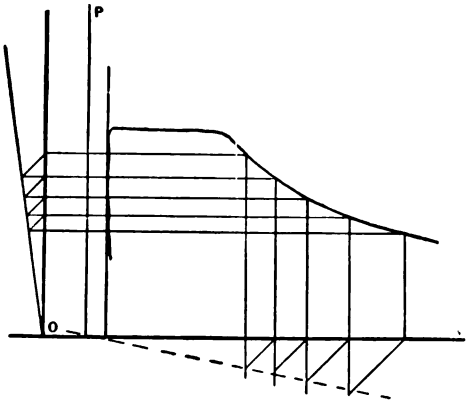

FIG. 1.

However, having recently certain indicator diagrams that I wished to study, and not knowing the clearance volume of the cylinder from which these were taken, I decided to test the method by applying it to a diagram taken from the cylinder of an engine working under much the same conditions, and for which the clearance volume was known. The result is given in Fig. 1, and even neglecting the fourth point, which is least likely to be accurate, the value of the clearance given by the construction is seen to be very unreliable, because of the reasons already referred to.

I next applied the construction to a diagram for the cylinder of which the clearance volume was not accurately known, but believed to be from 8 to 10 per cent. of the working volume. The corresponding result is given in Fig. 2, and shows a large negative clearance. This I could only explain by the give and take between the clearance volume and n mentioned above, but the result was so unexpected that I tried other diagrams

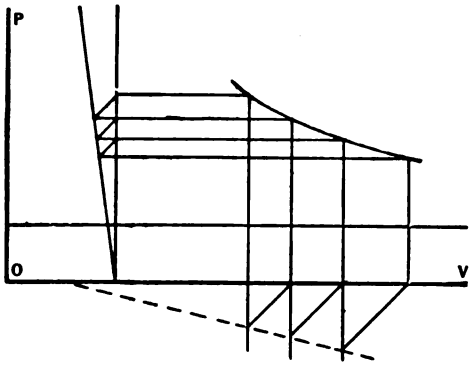

FIG. 2.—(O P *touches end of diagram.*)

taken from the same cylinder under as nearly as possible the same conditions. Figs. 3 and 4 give typical results from one diagram, using different values of β to obtain more or

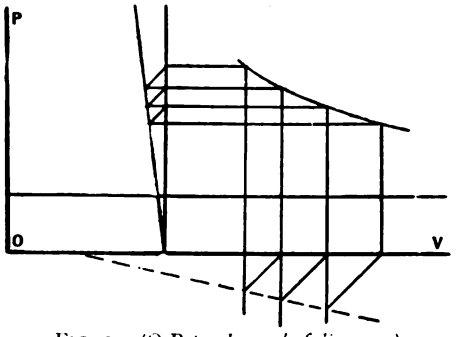

FIG. 3.—(O P *touches end of diagram.*)

less points, and it is seen that the position of the point of intersection found in each case is much the same.

The method having proved so untrustworthy in the above cases, I tried it on a diagram which would appear to suit it much

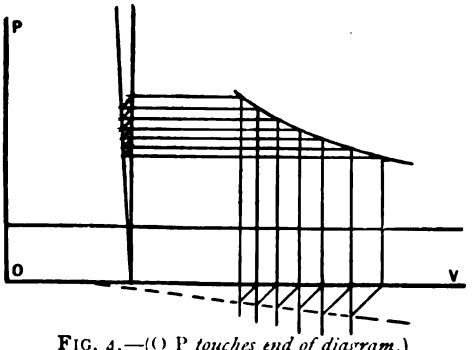

FIG. 4.—(O P *touches end of diagram.*)

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better, the point of cut-off in this case being earlier and the initial pressure high; the curve is much steeper, so that the points of intersection of the horizontal lines with the curve can be easily fixed, and the points on the straight line required extend over a much greater length and approach nearer to the required point of intersection, from which the vertical axis of pressure should be drawn. The result is given in Fig. 5, and it is seen that again the result is far from being correct.

It should be remembered that the diagrams considered have been selected at random, only the points stated governing the kind of diagram used in Fig. 5. We are thus forced to the conclusion that the distinctive application ascribed to the method is not practical, and its use should be limited to that originally given.

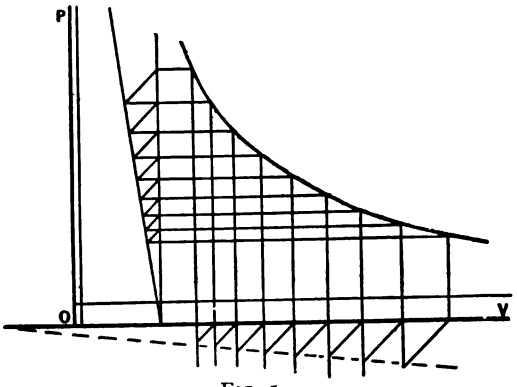

FIG. 5.

In order to determine whether the error in the value of the clearance volume found by the above method was due to errors in construction which could not be eliminated, or to the fact that the curve could not be exactly represented by an equation of the form pv^n = constant, I found the value of the clearance from the curve by a method based on the assumption that curve satisfies this equation, but which does not involve any construction, the accuracy of which can be doubted.

Considering a point on the expansion curve, p is the absolute pressure, v is the volume swept through by the piston, and c the clearance volume measured when set out on the indicator diagram in the ordinary way. Any scales may be used. Then

$$(1.) \qquad p(v + c)^n = k,$$

c, n and k being constants.

To find the value of c, since there are three unknowns, suppose that at three points on the expansion curve the corresponding pressures and piston-swept volumes are p_1v_1, p_2v_2, p_3v_3. Then, putting the above equation in the logarithmic form, we have

$$(2.) \quad \log p + n \log (v + c) = \log k,$$

and, substituting our particular values, we have

$$(3.) \quad \log p_1 + n \log (v_1 + c) = \log k.$$

$$(4.) \quad \log p_2 + n \log (v_2 + c) = \log k.$$

$$(5.) \quad \log p_3 + n \log (v_3 + c) = \log k.$$

Taking (3) and (4) together, we have

$$(6.) \quad \log p_1 - \log p_2 = n \log (v_2 + c) - n \log (v_1 + c).$$

Similarly, from (4) and (5),

$$(7.) \quad \log p_2 - \log p_3 = n \log (v_3 + c) - n \log (v_2 + c).$$

Eliminating n between (6) and (7)

$$\frac{\log p_1 - \log p_2}{\log p_2 - \log p_3} = \frac{\log (v_2 + c) - \log (v_1 + c)}{\log (v_3 + c) - \log (v_2 + c)}$$

In this equation, c is the only unknown, and therefore its value can be determined.

The following values were taken from Fig. 6, and correspond to the points A, B, and C:—

$p_1 = 4{\cdot}4$, $v_1 = 3{\cdot}24$; $p_2 = 3{\cdot}15$, $v_2 = 5{\cdot}12$; $p_3 = 2{\cdot}36$, $v_3 = 7{\cdot}75$.

Substituting these values,

$$\frac{\log p_1 - \log p_2}{\log p_2 - \log p_3} = 1{\cdot}159.$$

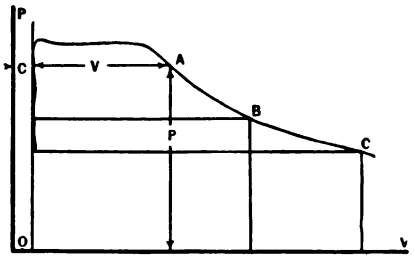

FIG. 6.

Taking c to be a variable, then to find its value, put

$$\frac{\log (v_2 + c) - \log (v_1 + c)}{\log (v_3 + c) - \log (v_2 + c)} = y.$$

Using the above values of v_1, v_2, and v_3, the following corresponding values of c and y are obtained:—

c	y	c	y
0·4	1·068	0	1·104
0·5	1·06	−0·5	1·16

To find the value of c, which will make y equal to 1·159, plot y and c on squared

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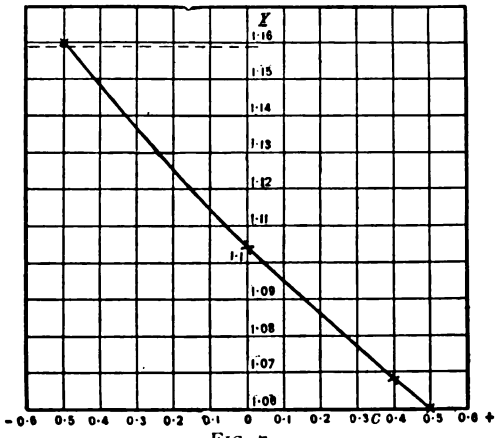

FIG. 7.

paper (see Fig. 7), and find where the curve cuts the line $y = 1 \cdot 159$. The corresponding value of c is that required, or the result in this case is $c = -0 \cdot 49$. This would correspond to a negative clearance of nearly 5·5 per cent. The true value was about + 6 per cent.

It therefore appears that we are not justified in our assumption that the expansion curve can be represented by an equation of the form pv^n = constant, for the purpose of finding the clearance.

I have not given any examples of gas-engine diagrams; as for them, Mr. Stoddard has shown that a curve is obtained instead of a straight line. This removes the assumption that the expansion curve exactly follows one law throughout its length, but still further increases the difficulty of fixing the required point of intersection with the axis of volume, and if we replace the straight line given in any of the figures by a curve drawn through the points, we do not obtain an accurate value for the clearance, and we are forced to the conclusion that it cannot be found from the indicator diagram.

A PETROL LOCOMOTIVE.

THE petrol motor is constantly having its sphere of utility extended and being put to new uses, either on the score of economy or convenience — generally the latter. A later development than the petrol-electric coach is a petrol locomotive. This locomotive has recently been built by the Wolseley Tool and Motor Car Company, Limited, of Birmingham. It runs on a two-feet nine-inch gauge, and is intended for shunting or other intermittent work of a like nature. It is engined with a 25 b.h.-p., two-cylinder, horizontal, petrol motor and, in running order, weighs about three tons. The cylinders are each six inches bore and seven inches stroke, and the motor runs normally at 600 revolutions per minute. The locomotive has a gear-box which provides two gear ratios in each direction, corresponding to about four and a half, and nine miles per hour respectively, the maximum speed being about twelve miles per hour. The greatest draw-bar pull on the low gear is 1250 lbs., which shows the efficiency of the transmission to be about 60 per cent. The locomotive is intended to deal with loads of about ten tons, although, when required, it can pull more than double this load at a slow speed on the level, under favourable conditions. When working constantly, the fuel consumption averages about one and a half gallons per hour, which, at first sight, appears prohibitive when compared with the coal consumption of a small steam locomotive; but it must be borne in mind that when not actually running, the fuel consumption is nothing, as the motor can be stopped when not required to move for a few minutes. There are many interesting departures from ordinary motor car lines to make the locomotive suitable for its work. The gear-box is mounted on one axle, and suspended in the manner used with respect to an electric motor on a tramcar, the power being transmitted to it from the motor by a "Renold silent chain." The circulating water is cooled by a radiator which has a draught of air induced through it by means of the exhaust up the funnel, which is in reality an exhaust silencer. The wheels are eighteen inches in diameter, and the wheel-base is three feet, enabling the locomotive to take a curve of only 28 feet radius.

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DEFECTS IN COTTON YARNS.

By J. H. DAWSON.

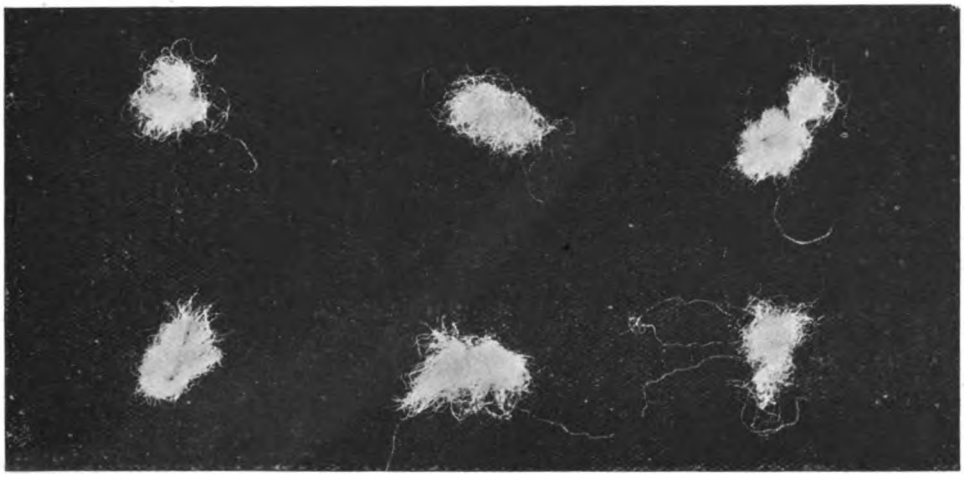

FIG. 1.—ORDINARY MOTES.
(*Magnified 2 diameters.*)

COTTON yarns are subject to various defects, and when these are present in any quantity, evil days are in store for those who have to deal with them. There are two distinct kinds of yarn, weft and twist, with several varieties of each. The weft or woof is practically a strand of cotton fibres twisted to the right, whilst the twist yarns are composed of fibres twisted in the opposite direction. The variety of cotton differs for weft and twist, but we are not concerned with this phase of the question in the present article. Weft is used as the filling of the various makes of cloth, whilst the twist is used as the framework. Twist yarns are also used for sewing cottons. A good weft yarn should possess regularity in colour, grist and strength; it should be pliable and clear of "motes," "nep," leaf, "slubs," "stains," "snarls," and thin places. Twist yarns should, above all, possess strength and elasticity; at the same time they should be as free as possible from the aforementioned faults.

The worst fault, perhaps, that can affect either weft or twist is "thin places." When these are present in the twist, the weaver is very severely handicapped: the yarn is constantly breaking in the loom, being unable to bear the strain put upon it in the weaving process. This causes the weaver extra work in the piecing up of broken ends, and a loss of wages through the loom being stopped. The cloth produced is unsatisfactory in appearance: nor is there the quantity turned off in a given time that there otherwise would be. In the weft "thin places" are equally annoying, causing "broken picks," "cracks," loss of production, and extra work for the weaver.

Thin places may be, and are caused in several ways, and at various stages of the spinning process. The most fruitful causes are irregular mixings, or too much waste in them; irregular draughts (air currents) in the blowing room; overdrafting in any of the machinery; bad rollers; "cutting" from any cause, in drawing, slubbing, roving, mule or ring; "stretching" or tight winding in any of the speed frames, or in the mule; and lastly intermediate or roving frame "single."

It will be seen from the above that there are many ways in which thin places can be produced; to trace the fault to its origin is a matter for practical deduction. The distance apart of the faults is the first clue. If the thin places come, say, every 64 inches, or the length of a mule stretch or draw, the probability is that they are caused by tight winding at this machine, and are "faller cut." If they are about every $3\frac{1}{4}$ inches, and the mule front roller is 1 inch in diameter, the yarn

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may be "roller cut." The cause of roller cutting may be any of the following:—bad piecings in the roller leathers (the fault of the roller coverer): a tooth or more out of the pinion wheel, back or front roller or carrier wheels, or any obstruction in the teeth of the same: set screws or nuts and bolts loose. In these instances the distance apart of the thin places will depend upon the "draft" in the rollers and the sizes of the wheels. Bad squares in the steel rollers will also cause cutting, but only, as a rule, once every draw or stretch.

If, upon careful examination, the cause is not found in the mule, it is as well to examine the product of the previous machines, that of the roving frame first, and using the same line of reasoning to endeavour to trace the fault. There is one thing the investigator can be certain of, *viz.*, if the thin places occur at equal distances apart the yarn is *cut*; if at irregular intervals, they are either due to stretching, or else produced in the mixing or blowing rooms. The material can be stretched at any of the speed frames by the use of unsuitable "rack" wheels. Sometimes the wheel itself will cause the stretching by winding the stuff too tight; whilst on the other hand, the frame tenter may be responsible for attempting to accelerate winding by "jacking" the frame up rather more than the amount required. Tight winding can be detected on the speed frames by an experienced eye, even whilst the frame is working; it may be noticed easily on the roving or slubbing when completed. The rovings, etc., from frames that are winding tight, always show places where the material is sunken below the level of the surroundings: these places present a "pulled in" appearance. Intermediate single and roving single are distinct types of thin places, and are caused by carelessness of the frame tenters.

After thin places, the most annoying fault

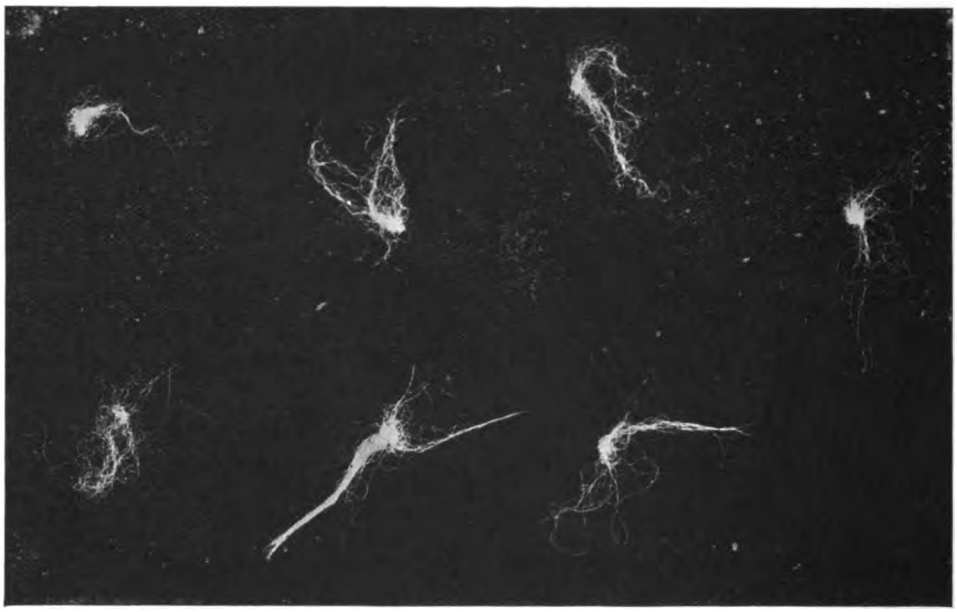

FIG. 2.—BEARDED MOTES.
(*Natural size.*)

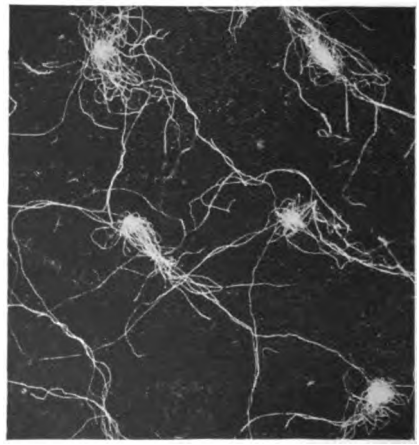

FIG. 3.—"NEPS."
(*Magnified about 2½ diameters.*)

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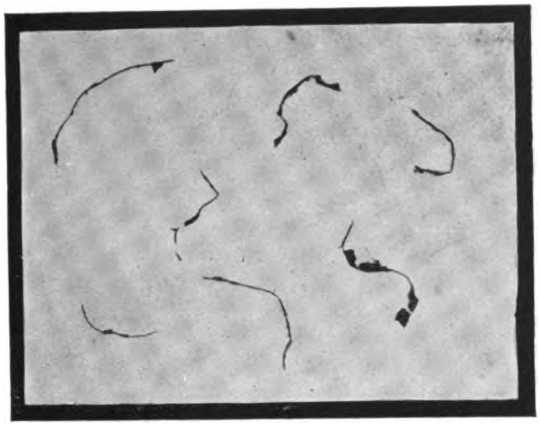

FIG. 4.—VEINS OF LEAF OF COTTON PLANT.
(*Natural size.*)

is the presence of "motes" in quantity. "Motes" (Figs. 1 and 2) consist of portions of the outside husk of the seed; as a rule they possess a fine mossy covering, composed of short immature fibres. These fibres have earned for the motes the title of "bearded motes"; it is owing to the "beard" that the motes are so objectionable. The short fibres attach themselves to the surrounding lint, owing to the natural convolutions explained in a previous article,* and are therefore very difficult to get rid of: in fact, it is almost impossible to clear them all from the cotton, and the consequence is that yarns containing them are of little value. Cloths woven from these yarns are sometimes irrevocably spoiled by the "bleeding" of these "motes" in the finishing process. A complaint of "bleeding motes" is one that a manufacturer does not care to receive.

The most practical way out of the "mote" difficulty is to convince the ginners of the evil results arising therefrom, and have the fault eradicated in its conception. The presence of these small particles in the lint arises from the seeds being smashed up in the ginning. If the seeds were all removed whole, "motes" could not be formed.

"Neps" (Fig. 3) are sometimes similar in appearance to motes, and may be often mistaken for them. The difference lies in the fact that a "nep" is composed entirely of fibre, and neither seed nor leaf enters into its composition.

The cause of the "nep" is the rolling together of one, two, or more fibres or part fibres, and the formation thereby of a small object varying in size from the smallest speck visible to the naked eye, to the size of a pin's head. Neps can be, and are caused at the gin, and at the carding engine, by faulty

* TECHNICS, Vol. I., pp. 227–230.

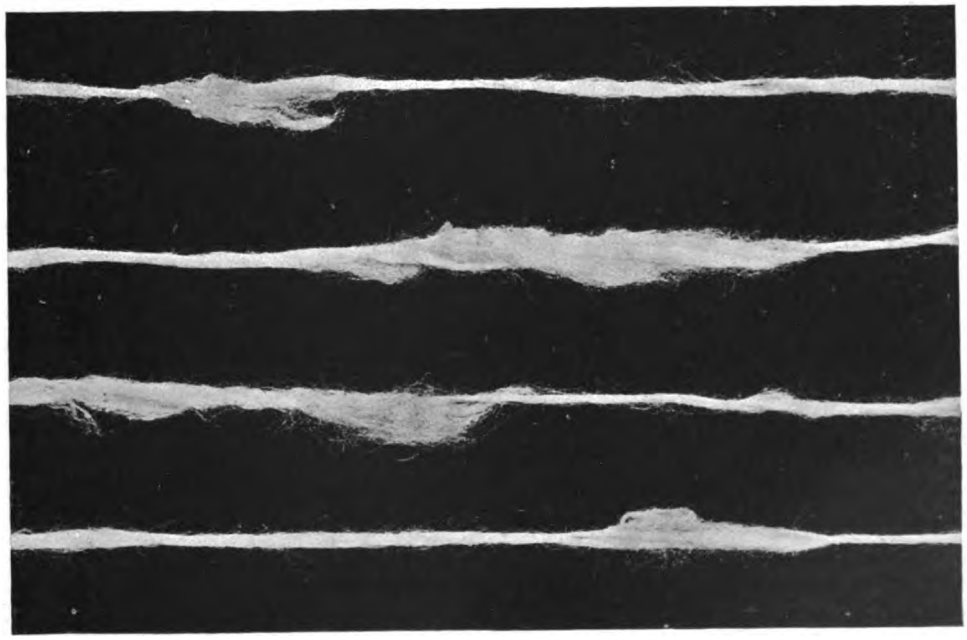

FIG. 5.—"BLACK SLUBS" CAUSED BY NEGLIGENCE IN CLEANING AND BRUSHING DOWN.
(*Natural size.*)

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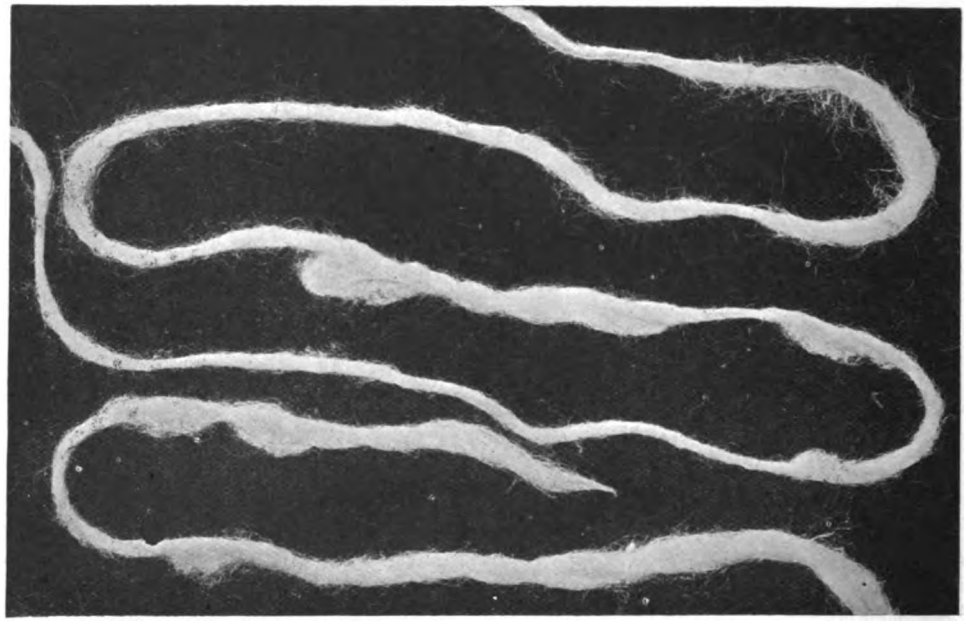

FIG. 6.—CLEARER WASTE SLUBS.
(*Slightly reduced.*)

setting of the various parts, or by overworking the machines. At the gin, heavy feeding, indifferent sharpening of the saws, careless setting of the same, or of the gin breasts, will directly cause "neps," and will also produce "cut" and "stringy" cotton, which will nep elsewhere in after processes. The carding engine will cause neps when fed with "stringy" cotton (caused either at the gin or at the scutcher) when too much weight is being put through in a given time, or when the card wire is unclean from want of stripping, dull from want of grinding, or "touching" through defective setting. Neps are very objectionable when present, but at the same time are also easily avoided; they differ from motes in this respect, and also in the fact that whilst the imperfect removal of the cotton seeds is sometimes (especially in damp seasons) almost unavoidable in certain makes of gins, neps are formed purely and simply through carelessness. Generally, "leaf" is not so difficult to get rid of as motes, but there are certain species of cotton plant the leaf of which has a very tough and tenacious vein, which seems to leave the surrounding portion and mix itself up with the fibres (Fig. 4). These veins go forward when incorporated with the lint cotton, and being spun into the thread, give a very ugly ap-

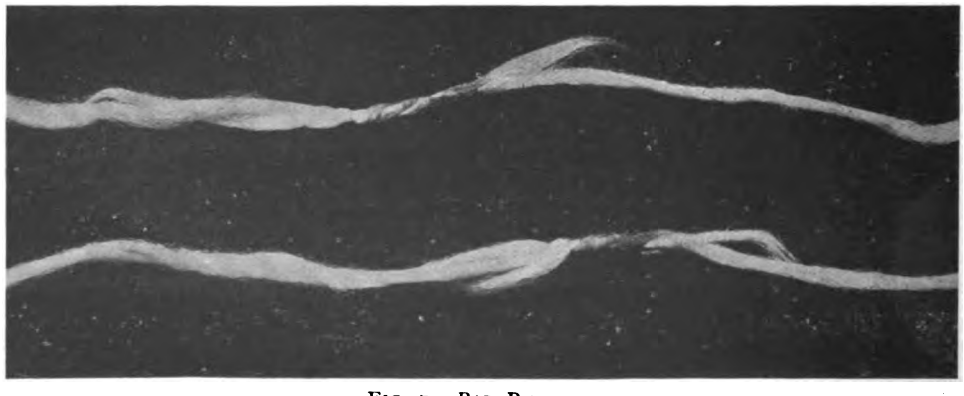

FIG. 7.—BAD PIECINGS.
(*Natural size.*)

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pearance to the cloth containing them. The only way to avoid this fault is to see that the machinery designed for removing leaf, etc. (*i.e.*, the blowing room machinery) is set and arranged so that the leaf is removed as far as possible without being broken up. Of course amongst the great army of cotton pickers, this very desirable result will never be attained. "Slubs" is the name given to a type of fault that can be caused in a score of different ways. All "slubs" are alike in one respect, *viz.*, they are an intolerable

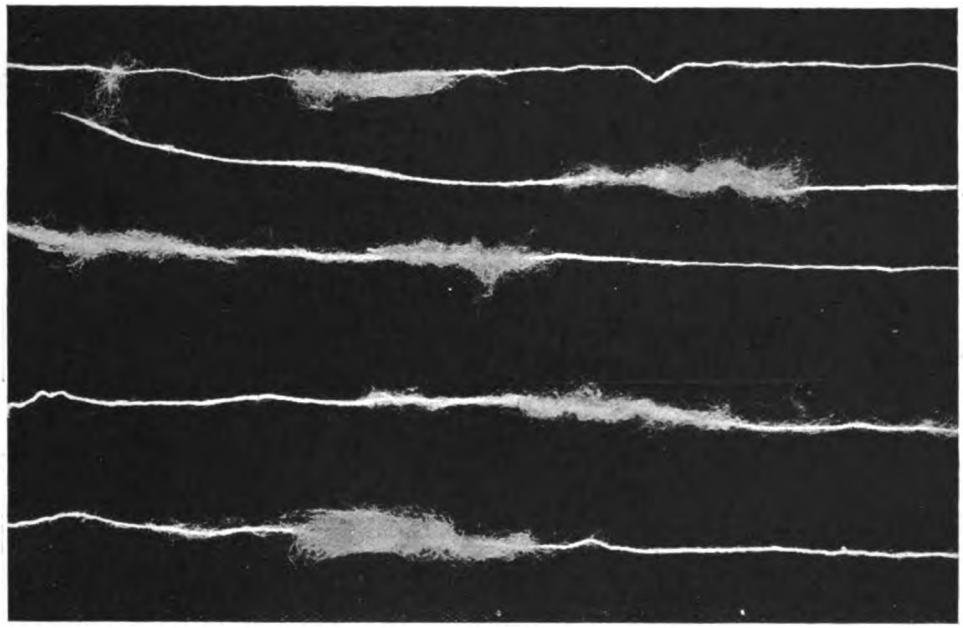

FIG. 8.—SLUBS CAUSED BY "DRYING DOWN" AT RING FRAME.
(*Natural size.*)

careful "picking" on the cotton plantation is the best remedy. It is clear that if the cotton were picked from the plant without the inclusion of leaf, the fault under discussion would not exist; but as there must of necessity be many degrees of proficiency nuisance and the cause of much inconvenience and loss to both employer and employee. Dirty and ill-kept clearers at the draw frame, slubbing, intermediate, roving and ring frames, and also at the mule, will cause "slubs" (Fig. 5). Clearer waste slubs

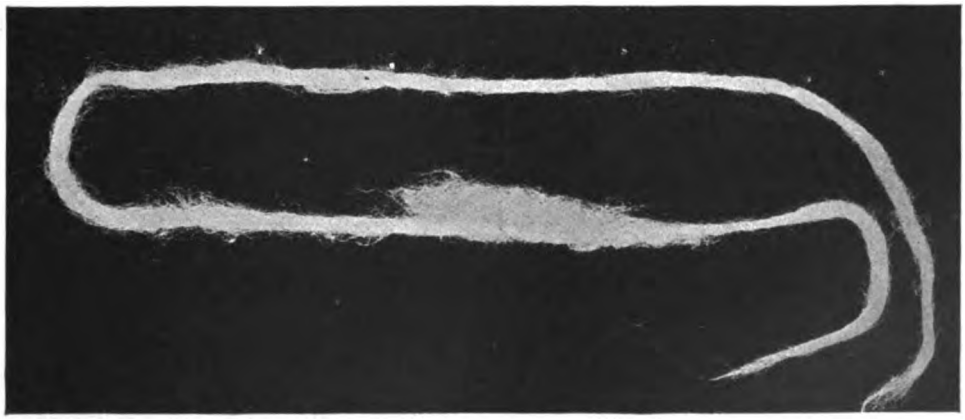

FIG. 9.—SLUBS FROM "FLYER LEG" AT ROVING FRAME.
(*Slightly reduced.*)

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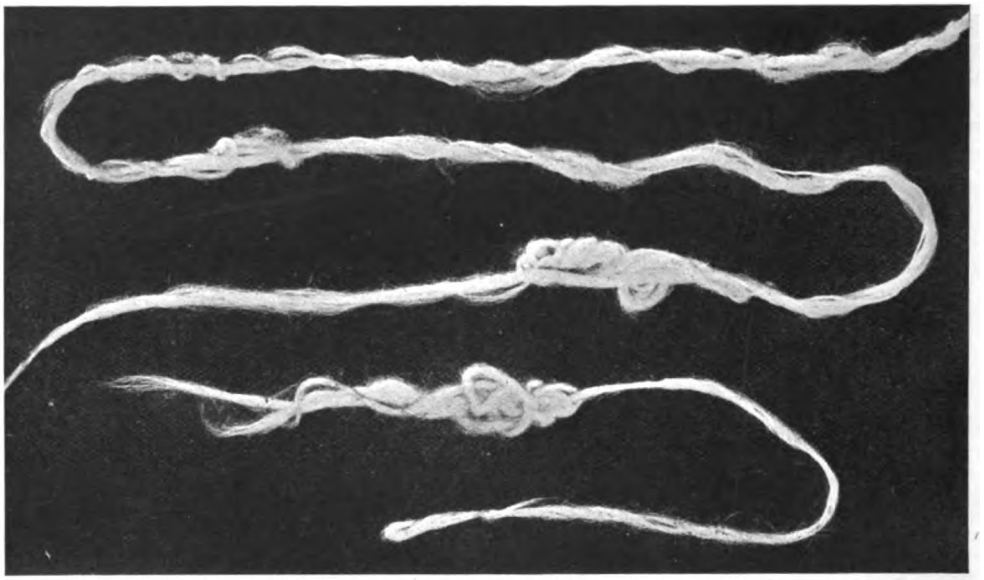

FIG. 10.—SLUBS CAUSED BY RUNNING DOUBLE. COMMONLY CALLED "THICK SLUBS."
(*Slightly reduced.*)

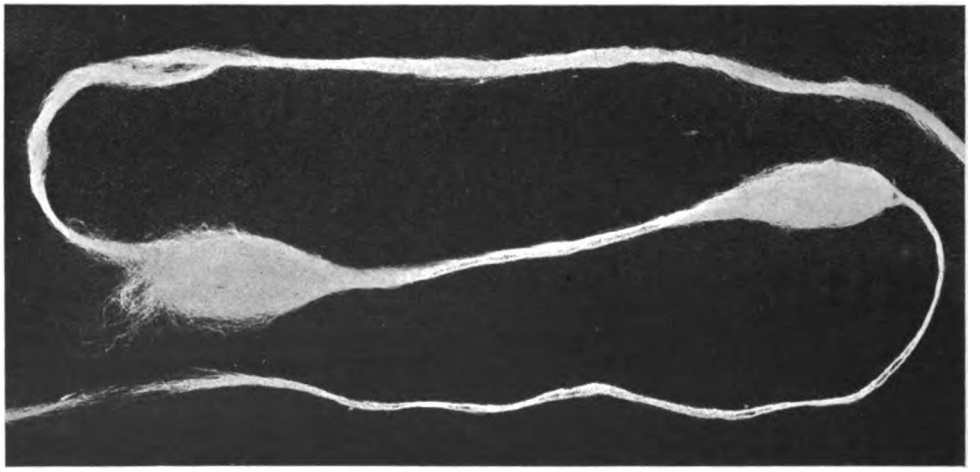

FIG. 11.—SLUBS CAUSED BY BROKEN END FLYING ABOUT AND CATCHING ON ITS NEIGHBOURS.
(*Slightly reduced.*)

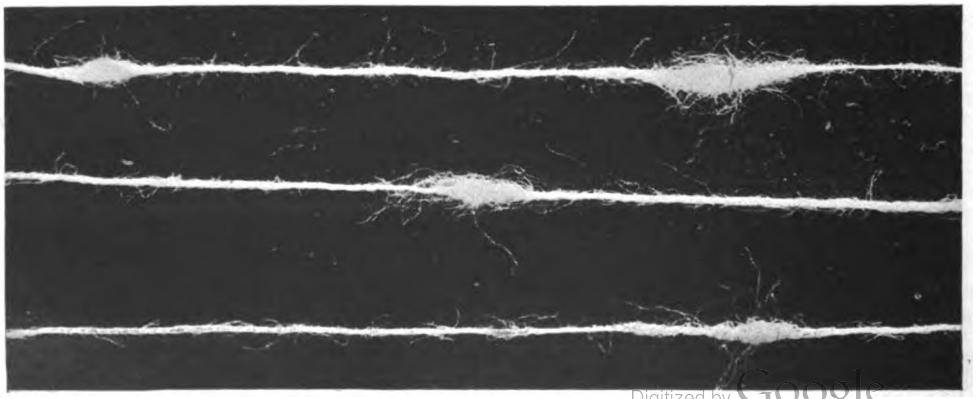

FIG. 12.—"CRACKERS," ONE OF THE WORST FAULTS IN YARNS, ESPECIALLY IN FRAME TWIST.
(*Magnified 3 diameters.*)

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can be easily distinguished upon examination (Fig. 6). Bad piecings at any of the above machines will cause a similar fault (Fig. 7).

A slub caused through a bad piecing has an appearance far different from a clearer waste slub. Neglect in "drying down" at the speed frames and ring frame will cause another different type of slub (Fig. 8). An accumulation of "fly" getting on the material from the flyers and pressers, the creels, or the roller beams at the slubbing, intermediate, and roving frames will form a slub of an appearance distinct from any of the others (Fig. 9). An hour spent in mastering the appearance of these and other types of slubs will pay the student or the practical man either, as the fact of being able to locate the cause of the fault at a glance will save endless trouble.

"Stains" are caused chiefly through the careless handling of lubricants, and when the fault is not detected before it gets into the weft, "black" weft is reported. A little careful examination and common reasoning will show where the stain has originated, and suggest means whereby the extent of the damage may be minimised.

"Snarls" are always caused at the machines where the finishing twist or turns are imparted to the thread, *i.e.*, the mule, ring, or throstle (when the latter is in use). It does not follow that the machine putting the snarls in is primarily responsible. Certainly the mule is responsible for snarls caused through slack winding; but there are snarls that form in small bunches, caused by the twist running into the thin places. If thin places in the roving are present in any quantity, sufficient "drag" or "carriage gain" can be put into the mule to stretch out all the snarls that will form in the circumstances, but the probability is that the remainder of the yarn will be overdrawn, and the cure may be worse than the original evil. If this is found to be so, the snarls must be allowed to go on whilst the cause of the fault is removed. Snarls in the ring and throstle frames can be caused by insufficient drag, slow running and carelessness in starting and stopping the frames. The small bunches of snarls caused through thin places in the mule, sometimes take another shape and name in the ring and throstle. The twist runs up into the thin places, but the snarls are very much smaller—in fact, a number of these snarls will run together and form a swelling on the thread almost like a large elongated nep. When the thread is pulled from opposite sides of one of these swellings, as much as two or three inches will sometimes pull out of one place, the yarn having a kind of elastic nature. Whilst pulling out, the swelling, of course, gradually decreases, and a kind of cracking noise is produced. From this fact the fault—a very objectionable one indeed—goes under the name of "crackers" (Fig. 12). Crackers can also be caused by overdrawing, or underdrawing the cotton, and by mixing long and short staples together.

THE FORTHCOMING OPTICAL CONVENTION IN LONDON.

An Optical Convention is to be held at the Northampton Institute, Clerkenwell, E.C., from May 31st to June 3rd. The president will be Dr. R. T. Glazebrook, Director of the National Physical Laboratory, and among the vice-presidents are the Earl of Rosse, the Earl of Crawford, Lord Kelvin, Lord Rayleigh, Lord Blythswood, Sir William Abney, Sir Howard Grubb, the Astronomer Royal, the Hon. Alban G. H. Gibbs, and Mr. Thos. Dallmeyer. The mornings will be devoted to papers and discussions on optical subjects. Papers are promised by Lord Rayleigh, Professors Poynting and Forbes, Dr. Watson, Mr. Dennis Taylor, Mr. T. H. Blakesley, Mr. J. W. Gordon, and others. Offers to read papers should be sent to the secretary of the Papers sub-committee, Mr. S. D. Chalmers, Northampton Institute, E.C., who will be glad to submit them to the committee. During the Convention an exhibition of optical and scientific instruments and appliances will be held in the great hall of the Northampton Institute. The exhibition promises to be of great general and scientific interest, and it is hoped that many novelties of British manufacture will be shown. A large number of persons and firms have promised to send exhibits. It is hoped that all those interested will apply for membership of the Convention, the subscription for which will be five shillings. The hon. secretary, Mr. F. J. Selby, Elm Lodge, Teddington, will be glad to receive the names of those wishing to join. A guarantee fund has been opened, and the total of guarantees and contributions now amounts to over £700. Promises of guarantees or donations should be sent to the hon. treasurer, Mr. E. B. Knobel, F.R.A.S., 32, Tavistock Square, W.C.

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REVIEWS.

"N" Rays. A collection of papers communicated to the Academy of Sciences. With additional notes and instructions for the construction of phosphorescent screens. **By R. Blondlot,** Professor in the University of Nancy. **Translated by J. Garcin.** pp. xii. + 83, with 10 illustrations and a number of phosphorescent screens. (London: Longmans, Green and Company, 1905.) Price 3*s.* 6*d.* net.

There is considerable doubt, in the minds of many people, whether N rays have any objective existence. Those interested in the subject will welcome a translation of Blondlot's memoirs; it should now be possible for anyone to re-perform the experiments which are said to have established the existence of N rays, and if this were done by capable experimenters, the vexed question of the existence of these rays might be finally answered. On reading the book before us, one cannot but feel that comparatively little attention has been devoted to the avoidance of errors of observation—errors which are so likely to occur in viewing a small, dimly luminous object in a dark room. The so-called objective experiments, which were performed by photographing an electric spark, under the action of N rays and in the absence of this action, appear to be scarcely convincing; however, it might be worth while for independent investigators to re-perform these experiments.

Microscopic Analysis of Metals. By Floris Osmond. Edited by J. E. Stead, F.R.S., F.I.C. pp. x. + 178, with 100 reproductions of photo-micrographs, and two folding diagrams. (London: Charles Griffin and Company, Limited, 1904.)

The value of the metallographic work of M. Floris Osmond has gained a world-wide recognition, and the book before us should be in the possession of everyone interested in the microscopic analysis of metals. The beautiful photo-micrographs with which the volume is illustrated are certainly better than any others which have been published; indeed, it is difficult to imagine any possible improvement on them. The letter-press is clear and concise, and altogether it must be admitted that the author makes out a good case for the allotropic theory of metals. The arguments for and against the allotropic theory are too numerous and intricate to be dealt with in a brief review; it must suffice to say that, under the able editorship of Mr. Stead, the lucid reasoning of M. Osmond has lost nothing in being rendered into English.

Electric Lighting for Amateurs. Edited by Percival Marshall, A.I.Mech.E. pp. 80. (London: Percival Marshall & Co.). Price 6*d.* net.

This handbook contains practical hints on the subject of fitting up small electric lighting installations. While battery plants are largely dealt with, the last chapter contains information relative to laying down a small power system of lighting. Forty-five line drawings are used to illustrate the text.

An Introduction to Metal Working. By J. C. Pearson. pp. xvi + 110 (London: John Murray, 1904.) Price 2*s.* net.

Few subjects possess greater inherent interest than that of metal working. It was at one time contended that practical knowledge in engineering could not be obtained from books: while there is some truth in this statement, since skill in the use of tools can only be acquired by practice, yet there is an aspect of practical work which can only be obtained from books or from oral instruction. This aspect is dealt with by Mr. Pearson, and the hints given will certainly prove of value to the young mechanic. Practically every branch of elementary engineering workshop practice is ably described, the whole being illustrated by good diagrams and half-tone blocks. A useful index is provided.

New Streets: Laying-out and Making-up. By A. Taylor Allen, Engineer and Surveyor, Portslade-by-Sea Urban District Council. pp. 175, with 11 illustrations. (London: The Sanitary Publishing Company, Limited, 5, Fetter Lane, Fleet Street, 1904.) Price 3*s.* net.

The author of this book has aimed at giving, in a condensed form, the information necessary to a surveyor in carrying out work under the Public Health Act, 1875, and the Private Street Works Act, 1892. The subjects dealt with are the laying out and construction of new streets, the making up of private streets, and the drawing up of plans, specifications, estimates, and appointments. Design and taste are not considered, nor are the legal aspects of the various provisions of the acts: attention is exclusively confined to the practical way of conforming to the various enactments. Much information of a most useful character has been condensed by the author into a limited space; but the book might have been improved if the illustrations had been placed facing the text in which they are described, instead of at the end of the book.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

TURBINE.—Explain any graphical method of determining the form of the blades for an impulse turbine by the use of the idea of the "turbine rod." Assuming that friction in the guide blade is equivalent to a loss of 7 per cent., and that another 7 per cent. is rejected in the tail race, work out the necessary data for the graphical construction, and find the maximum efficiency of the turbine.—*London University, B.Sc., Eng.*, 1904.

By the term "turbine rod," an ideal form of turbine wheel which has an infinitely large radius is understood. If the conception were actually realised, the turbine wheel would somewhat resemble a step-ladder laid horizontally, mounted on wheels and propelled by jets of water striking against the steps, which correspond to the vanes.

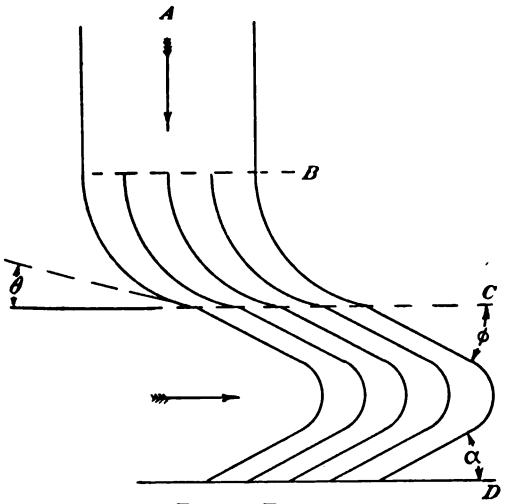

FIG. 1.—TURBINE.

In the upper part of Fig. 1, at A, a body of water may be supposed to be moving downwards under a total head of H feet. At the level of the line B, the water meets a number of fixed curved guide vanes, which deflect its direction until the end of C is reached, at which level it enters a second set of curved vanes, which may be regarded as fixed to a frame which moves in a straight line in the direction of the arrow. When the water reaches the level D, it should retain sufficient momentum to enable it to clear itself from the wheel, and at this point it may be regarded as entering the tail race.

In order to prevent loss of head by shock, the tangent of any vane upon which the water is flowing should coincide with the direction of the water, and it is the object of the graphical constructions to determine such tangents, as also the tangents to the vanes at the points where the water issues.

If, then, the head and the velocity of the water at the part A are respectively equal to H feet and V feet per sec., then

$$V^2 = 2gH.$$

The tangents to the vanes at B must be vertical, since the water is flowing vertically downward. At the level C the water issues with a diminished head (and therefore a diminished velocity) on account of friction.

Denoting by H_C and V_C respectively the head and the velocity at this point,

$$V_C^2 = 2gH_C,$$

and since H_C results from the diminution of H by 7 per cent.,

$$V_C^2 = 2g \times 0{\cdot}93\ H = 1{\cdot}86\,gH,$$

and therefore $V_C = \sqrt{1{\cdot}86\,gH}$.

Taking $g = 32$,

$$V_C = 7{\cdot}7\sqrt{H}.$$

Since the velocity of issue at D is that due to 7 per cent. of the head H, then if V_D is the velocity of issue,

$$V_D^2 = 2g \times 0{\cdot}07\ H,$$

and hence

$$V_D = \sqrt{0{\cdot}14\,gH} = 2{\cdot}12\sqrt{H}.$$

V_D is set off to scale vertically, and V_C is set off to represent the absolute velocity of the water as it leaves the tips of the fixed vanes (Fig. 2).

V_C is the resultant of the vertical velocity V_D and a horizontal velocity V_A. The tangents to the tips of the fixed vanes must therefore make an angle θ with the horizontal.

It is now necessary to define the velocity of the water relative to the wheels; if the wheel velocity be denoted by V_W, the horizontal component of the velocity of the water relative to the wheel is $V_A - V_W$. Since the wheel has no vertical motion, V_T in Fig. 2 will represent the

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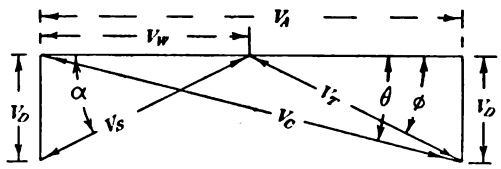

FIG. 2.—TURBINE.

velocity of the water relative to the wheel, and ϕ is the angle to the horizontal of the tangent to the wheel vanes at C.

After coming in contact with the wheel vanes, the water is gradually deflected by them, so that it finally leaves the wheel with no absolute horizontal velocity whatever, but with the vertical velocity V_D.

In order to fulfil this condition the water must issue with a horizontal velocity toward the left, equal to the absolute velocity V_W of the wheel, which moves to the right. Compounding the velocities V_W and V_D, we get V_S in the figure, and the angle α at which the tangent to the lower tips of the wheel vanes is inclined to the horizontal.

The value of V_W is not deduced from any of the data given, but may be taken as $\frac{V_A}{2}$.

The data, then, for the graphical construction shown in Fig. 2 are

$$V_D = 2{\cdot}12\sqrt{H}$$

$$V_C = 7{\cdot}7\sqrt{H}$$

$$V_A = \sqrt{V_C^2 - V_D^2} = 7{\cdot}4\sqrt{H}.$$

The angles of the tangents to the vanes are θ, ϕ, and α, and

$$\sin\theta = \frac{V_D}{V_C},\ \tan\phi = \frac{V_D}{V_A - V_W},\ \text{and}\ \tan\alpha = \frac{V_D}{V_W}$$

The shape of the fixed vane may be determined by joining the tangents at the tips of the vanes by a smooth curve.

In fixing the shape of the wheel vane, it is desirable to make the length of the vane as short as possible, in order to minimise loss by friction. This is shown in Fig. 3, where the

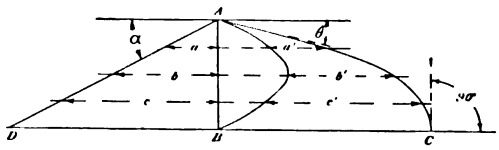

FIG. 3.—TURBINE.

curved line AC represents the absolute path of the water, and is any smooth curve having the given tangents at A and C.

AB is a vertical line which represents the width of the turbine wheel, AD is drawn at the angle α to the horizontal, and BC may be made equal to BD.

A number of horizontal lines having been drawn, the distances a, b, c, etc., are set off to the left of the curve AC as a^1, b^1, c^1, etc., and a curve passing through the left-hand terminations of these lines is the required shape of the wheel vane.

It should be noticed that if the distance BC is made equal to BD, then we shall obtain a short vane, but the vertical tangent to the absolute path of the water at C might have been drawn anywhere to the right of the line AB without departing from any of the conditions laid down. The result of doing so, however, would have been a longer vane and, therefore, a greater loss by friction.

As the construction so far applies only to a turbine wheel of infinite radius, a modification will be needed for the actual wheel, which must have a finite radius. In Fig. 4, the lines B, C,

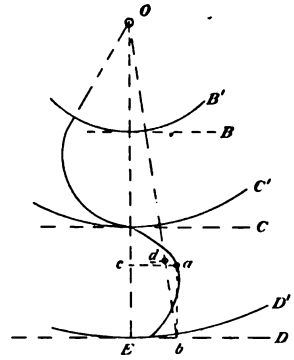

FIG. 4.—TURBINE.

and D correspond to those in Fig. 1, and the vanes of the turbine rod are represented by curved lines. O is the centre of the turbine wheel, and the arcs B^1, C^1 and D^1 show the limits of the actual guide blades and turbine wheel. For any point in either of the curves, such as the point a, a corresponding point such as d may be found. By projecting the first point perpendicularly upon the lines OE and ED the points c and b are obtained. The points O and b are joined by a straight line, and with centre O the arc $c\,d$ is described, which gives the required point d in O b.

The maximum efficiency of the turbine is

$$\frac{\text{Head usefully employed}}{\text{Total head}} = \frac{V_A^2}{2g} \div \frac{V^2}{2g}$$

$$= \frac{V_A^2}{V^2}$$

$$= \frac{V_C^2 - V_D^2}{V^2}$$

$$= \frac{0{\cdot}86 \times 2gH}{2gH};$$

and hence the maximum efficiency = 86 per cent.

BOILER. — Find the relationship between the pressure inside a vessel and the stress in the end-plate of given diameter (d), thickness (t) and radius of curvature (R), considering two cases: (a), end-plate continuous with sides; (b), end attached by means of bolts or screwed into end of tube, this being treated as if plate were supported but not fixed at circumference (except partially in the matter of tilting).

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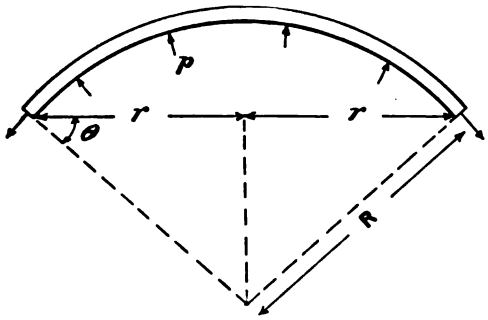

FIG. 1.—BOILER.

Taking the case of the thin curved end attached to the sides, the tension in the material is f lbs. per square inch along a tangent.

The total tension on the circumference

= total area of section × f
= $2\pi r t f$ where t is the thickness.

Vertical component of this force

$$= 2\pi r t f \cos\theta$$
$$= 2\pi r t f . \frac{r}{R}$$
$$= 2\pi t f \frac{r^2}{R}$$

And this is balanced by the vertical component of the internal pressure, which equals $\pi r^2 p$ lbs. where p is the internal pressure per square inch. Equating these quantities, we get

$$p R = 2 t f.$$

The treatment of the problem on the assumption that bending takes place is long and tedious, and not suitable for introducing here. Some information may be obtained in Todhunter and Pearson's "History of the Theory of Elasticity." Perry's "Applied Mechanics" may be of some assistance.

Unwin's formulæ are correct. Beware of using pocket-book formulæ unless you thoroughly understand how they are obtained.

HYDRAULICS.—A central hydraulic power station can deliver 1200 H.P. with a working pressure of 750 lbs. per □ inch. If power mains are 6 inches in diameter, how many would be required in order to convey this power? Show by sketches how such power mains are connected at the joints.—*London University, B.Sc. (Eng.)*, 1903.

Let V be the volume in cubic feet swept out by the hydraulic pump plungers per minute.

The work done by them on the water per minute

= pressure per square foot × volume in cubic feet swept out by plungers.
= 750 × 144 × volume of water pumped per minute in cubic feet.

H.P. of pumps

$$= \frac{\text{work done per minute in foot-lbs.}}{33{,}000}$$
$$= \frac{750 \times 144 \times \text{volume of water per minute}}{33{,}000}$$
$$= 3{\cdot}25 \times \text{volume of water per minute};$$

and

$$\text{volume of water per minute} = \frac{1200}{3{\cdot}25}$$
$$= 370 \text{ cubic feet.}$$

Assuming a velocity of flow of 3 feet per second, or 180 feet per minute, we have

$$370 \text{ cubic feet per minute} = 180 \times n \times \frac{\frac{\pi}{4} \times 36}{144}$$

where n = number of 6-inch pipes required.
= 10·4, or say, 11 pipes.

For a drawing of pressure pipe connections, see Unwin's "Machine Design," Chapter 6, Article 106, or any book on machine drawing.

OPTICS.—Draw a curve showing, in the case of a convex lens, the connection between the distance of the object from one principal focus, and the distance of the image from the other.—*London University, Inter. Sci.*, 1903.

Let distances measured in a direction opposite to that of the incident rays be positive, distances measured in the reverse direction being negative. Let the *first principal focus* be that position of a point object on the axis of the lens, which renders the rays, transmitted by the lens, parallel to the axis, and let this point be at a distance f_1 from the lens. Let rays initially parallel to the axis form an image at the *second principal focus* of the lens, and let this point be at a distance f_2 from the lens (f_2 is the *focal length* of the lens). Then if the object, when at a distance U from the first principal focus, forms an image at a distance V from the second principal focus, it can be readily proved that the magnification m (ratio of height of image to height of object) is given by either of the equations

$$m = \frac{f_2}{U}$$
$$m = -\frac{V}{f_2};$$
$$\therefore \frac{f_2}{U} = -\frac{V}{f_2},$$

which gives $$U V = -f_2^2 \quad . \quad . \quad . \quad . \quad (1)$$

Equation (1) represents a pair of rectangular hyperbolas. Taking the origin O_1 (Fig. 1), and plotting U horizontally and V vertically, we obtain the required curves; when U is positive, V must be negative, and when U is negative, V must be positive, in order that U V shall have a negative value.

If u is the distance of the object from the lens, and v is the distance of the image from the lens, we have

$$u = f_1 + U = U - f_2$$
$$v = V + f_2$$

substituting in (1), we obtain

$$(u + f_2)(v - f_2) = -f_2^2$$

On simplifying, we obtain

$$u v - u f_2 + v f_2 = 0.$$

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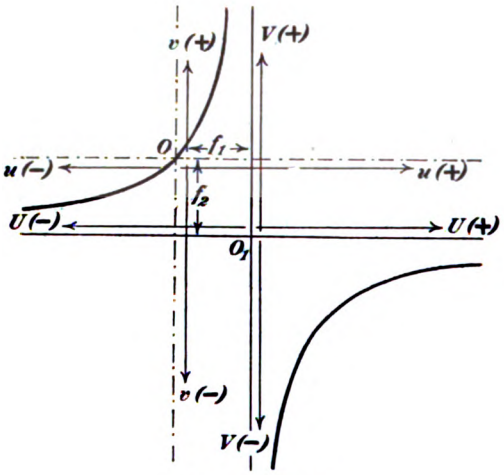

FIG. 1.—OPTICS.

Dividing through by $u\,v\,f_2$, and rearranging terms, we obtain the well-known equation

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots (2)$$

The curves represented by (2) are of course the same as those represented by (1), the only difference being that the origins chosen are different. If O is taken as the origin for curves (2), then the straight lines

$$u = f_1 = -f_2$$
$$v = f_2$$

are the asymptotes to the rectangular hyperbolas. Equation (1) represents the same curves referred to the asymptotes as axes.

Equation (1), although not given in many of the text-books on optics, is exceedingly useful in carrying out calculations with respect to lenses; the same equation applies to a concave (divergent) lens, where f_1 is negative, and f_2 is positive.

PRESSURE.—A closed surface in the form of the surface formed by the revolution of the curve

$$R = a\,(1 - \cos\theta)$$

is just filled with water and held with the cusp upwards, and the axis vertical; calculate the whole pressure and the resultant vertical pressure on its surface, and prove that these quantities are in the ratio 263 : 210. — *Besant's Hydromechanics* (Ed. V., page 39).

The given equation represents the cardioide. We suppose the initial line to be the axis of revolution.

It is easily seen that the resultant vertical pressure on the curved surface is equal to the weight of the contained fluid. The element of area being $r\,d\theta\,dr$, the element of volume is

$$2\pi\,yr\,d\theta\,dr = 2\pi\,r^2 \sin\theta\,d\theta\,dr,$$

where y is the ⊥ distance of the element of area from the axis.

If w be the weight of unit volume of water, then the resultant vertical pressure is given by

$$V = w\int_0^{\pi}\int_0^{a(1-\cos\theta)} 2\pi\,r^2\,dr\,\sin\theta\,d\theta$$
$$= \frac{2\pi}{3}w\int_0^{\pi} a^3\,(1-\cos\theta)^3\sin\theta\,d\theta$$
$$= \frac{2\pi}{3}a^3 w\left[\frac{(1-\cos\theta)^4}{4}\right]_0^{\pi}$$
$$= \frac{8\pi\,a^3}{3}w$$

To find the whole pressure it is necessary to first express the depth (below the highest point) of any point on the surface.

The slope of the tangent at any point with reference to the radius vector is given by

$$\tan\psi = R\frac{d\theta}{dR} = 2\sin^2\frac{\theta}{2}\cdot\frac{1}{\sin\theta} = \tan\frac{\theta}{2}.$$

From this we easily deduce that the depth of the origin, O, is $\frac{a}{4}$.

The pressure at the point (R,θ) is therefore

$$\frac{a}{4} - R\cos\theta.$$

The element of length ds is given by

$$(ds)^2 = R^2\,d\theta^2 + d\,R^2$$
$$= 2a^2(1-\cos\theta)\,d\theta^2.$$

Hence
$$ds = 2a\sin\frac{\theta}{2}\,d\theta,$$

and the element of surface is

$$2\pi R\sin\theta\,.\,2a\sin\frac{\theta}{2}\,.\,d\theta.$$

The whole pressure is given by

$$W = w\int_0^{\pi}\left(\frac{a}{4} - R\cos\theta\right)4\pi\,a\,R\sin\theta\,.\sin\frac{\theta}{2}\,d\theta.$$

By a few simple reductions this becomes

$$W = w\pi a^3\left\{4\int_0^{\pi}\sin^4\frac{\theta}{2}\cos\frac{\theta}{2}\,d\theta - 32\right.$$
$$\left.\int_0^{\pi}\sin^6\frac{\theta}{2}\cos\frac{\theta}{2}ds + 64\int_0^{\pi}\sin^8\frac{\theta}{2}\cos\frac{\theta}{2}d\theta\right\}$$
$$= w\pi a^3 8\left\{\frac{1}{5} - \frac{8}{7} + \frac{16}{9}\right\}$$
$$= w\pi a^3 8\times\frac{263}{315}$$

Hence
$$\frac{W}{V} = \frac{263}{105}.$$

The given answer appears to be incorrect.

SERIES.—The ordinary proof that the series $1 + \frac{1}{2} + \frac{1}{3} + \ldots$ is divergent consists in showing that it can be put in the form $1 + \frac{1}{2} + \frac{1}{2} + \ldots$ It seems to be a serious objection that the number of terms necessary to make up $\frac{1}{2}$ very rapidly increases, and finally becomes infinite. Is there any proof that the series is divergent, free from this objection?

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The given series *cannot* be put in the form $1 + \frac{1}{2} + \frac{1}{3} + \ldots$ The usual proof consists in showing that the series must be greater than any finite number of halves. Perhaps the following way of looking at the matter may remove the objection. It is a necessary and sufficient condition for the convergency of any series that the sum of the series after the nth term must have zero as its limit; when all the terms are positive this includes the statement that the limiting value of each term must be zero.

In the given case each term after the nth tends to zero as its limit, but the sum of n terms after the nth is

$$\frac{1}{n+1} + \frac{1}{n+2} + \ldots \frac{1}{2n},$$

which is greater than

$$\frac{1}{2n} + \frac{1}{2n} + \ldots \text{ to } n \text{ terms},$$

which is $\frac{1}{2}$. In other words, the sum of the terms after the nth does not tend to the limit 0 but to something $> \frac{1}{2}$. The series cannot therefore be finite.

Notwithstanding the fact, then, that as we go along the series more and more terms are necessary to add up to some number $> \frac{1}{2}$, yet, however many terms of the series we take, the remainder must be greater than $\frac{1}{2}$.

To get a grip of the thing, find a number of terms for which the sum is greater than a million.

The first two terms $= \frac{3}{2}$
The next two terms $> \frac{1}{2}$
The next four terms $> \frac{1}{2}$
etc.

Hence, if n is the number of these sets necessary, we shall be quite safe in taking $\frac{n}{2} = 10^6$.

$$\text{But } 2 + 4 + 8 + \ldots \text{ to } n \text{ terms} = 2\,\frac{2^n - 1}{1}.$$

Hence the sum will be greater than 10^6 if we take 10^{20} terms. This is, of course, a large but a perfectly definite number.

However big a number we choose, we can always calculate a number of terms whose sum will certainly be greater than the given number.

POLYGON.—Please tell me the best and most recent Text-books on Practical Mathematics up to the Board of Education, Stage III. Standard; also the best practical Treatises on the Infinitesimal Calculus sufficient for a highly trained mechanical engineer, and for the advanced study of Hydromechanics?

Castle's Advanced Practical Mathematics contains nearly all that is necessary, and indeed, goes considerably beyond the requirements in some directions (Macmillan, 6*s.*).

Perry's Calculus for Engineers may be described as *the* calculus for engineers. The man who has really mastered it must be a good engineer as well as a good mathematician (Arnold, 7*s.* 6*d.*).

For the advanced study of Hydromechanics, some knowledge of Partial Differential Equations and Spherical Harmonics is necessary. Forsyth's Differential Equations (Macmillan, 14*s.*); the Spherical Harmonics necessary are given in such books as Lamb's Hydromechanics.

SOLID GEOMETRY.—A line of constant length has its extremities on two given straight lines: find the equation to the surface generated by it, and show that any point in the line describes an ellipse.—*C. Smith's Solid Geometry, p.* 35.

The work will be much simplified by a proper choice of axes and origin.

Choose as the axis of z the shortest distance between the given lines, and take the origin midway. Choose as axis of x the line through the origin bisecting the acute angle between the lines, and the axis of y bisecting the obtuse angles.

If α be the angle (acute) between the given lines, and $m = \tan \frac{\alpha}{2}$, then the lines are the intersections of the planes

$$\left.\begin{matrix} y = mx \\ z = c \end{matrix}\right\} \text{ and } \left.\begin{matrix} y = -mx \\ z = -c \end{matrix}\right\} \text{ respectively;}$$

$2c$ being the shortest distance between the given lines.

Let (x_1, y_1, c) and $(x_2, y_2, -c)$ be any two points on the lines, such that

$$\sqrt{x_2 - x_1^2 + y_2 - y_1^2 + 4c^2} = 4a^2 \quad . \quad . \quad (1)$$

where $2a$ is the given length of moving line.

The equations to the line joining these points are

$$\frac{x - x_2}{x_1 - x_2} = \frac{y - y_2}{y_1 - y_2} = \frac{z + c}{2c}$$

or

$$\frac{x - x_2}{x_1 - x_2} = \frac{y + mx_2}{m(x_1 + x_2)} = \frac{z + c}{2c}$$

$$= \frac{y + mx}{2mx_1} = \frac{y - mx + 2mx_2}{2mx_2}.$$

Hence

$$mx_1 = c\,\frac{(y + mx)}{z + c}$$

$$mx_2 = c\,\frac{(y - mx)}{z - c}.$$

Substitute in (1), and we obtain

$$\frac{c^2}{m^2}\left\{\frac{y - mx}{z - c} - \frac{y + mx}{z + c}\right\}^2 + c^2\left\{\frac{y - mx}{z - c} + \frac{y + mx}{z + c}\right\}^2 = 4(a^2 - c^2).$$

On simplifying, this becomes

$$(cy - mxz)^2 + m^2(yz - mcx)^2 = \frac{a^2 - c^2}{c^2}\,m^2(z^2 - c^2) \quad (2)$$

the surface required, for it is the relation which must be satisfied by any point P (x, y, z) on the moving line.

If the point P divides the length $2a$ in a fixed ratio $p : q$, then

$$x = \frac{qx_1 + px_2}{p + q}, \quad y = \frac{qy_1 + py_2}{p + q}, \quad z = \frac{qc - pc}{p + q} \quad . \quad (3)$$

hence z is constant (as is indeed obvious), and the point (x, y, z) moves in a plane.

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The equation to the locus of P may therefore be most easily obtained by substituting

$$z = \frac{q-p}{p+q}c = b \text{ (say)}, \text{ in equation (2).}$$

On making this substitution and squaring out, we get

$$m^2x^2(b^2+m^2c^2)+y^2(c^2+m^2b^2)-2mbcxy(1+m^2) = \frac{a^2-c^2}{c^2}m^2(b^2-c^2)^2$$

as the equation to the locus of P. This represents an ellipse for

$$m^2b^2c^2(1+m^2)^2 < m^2(b^2+m^2c^2)(c^2+m^2b^2).$$

The locus might also have been obtained directly from (3).

By taking P as the mid-point, the locus becomes

$$m^4x^2+y^2 = (a^2-c^2)m^2.$$

CYCLOID.—Find the co-ordinate of the centroid of the area of the cycloid $x = a(\theta + \sin\theta)$, $y = a(1-\cos\theta)$, and the volumes formed by revolution

(1) round the base ($y = 2a$),
(2) about axis ($x = 0$),
(3) about tangent at vertex.

—*Edwards' Int. Cal., p.* 208.

It can easily be seen from a figure that (i.) the origin is at the vertex, (ii.) the axis of x is the tangent there, (iii.) the base is the line on which the circle rolls.

Since $\cos\theta = \cos(-\theta)$ the curve is symmetrical about the axis of y, hence the centroid lies on the axis of y and $\bar{x} = 0$.

The area is given by

$$A = 2\int_0^{\pi a}(2a-y)\,dx$$

$$= 2a^2\int_0^{\pi}(1+\cos\theta)^2\,d\theta$$

$$= 2a^2\int_0^{\pi}\left(1+2\cos\theta+\frac{1+\cos 2\theta}{2}\right)d\theta$$

$$= 2a^2\left[\tfrac{3}{2}\theta+2\sin\theta+\frac{\sin 2\theta}{4}\right]_0^{\pi}$$

$$\therefore A = 3\pi a^2.$$

The first moment about the axis of x is given by

$$Ay = 2\int_0^{\pi a}\left(2a-y\right)\left(\frac{2a+y}{2}\right)dx$$

$$= a^3\int_0^{\pi}(4-1-\cos\theta^2)(1+\cos\theta)\,d\theta$$

$$= a^3\int_0^{\pi}\{4+4\cos\theta-\sin^2\theta(1-\cos\theta)\}\,d\theta$$

$$= a^3\int_0^{\pi}\left\{4+4\cos\theta-\frac{1-\cos 2\theta}{2}+\cos\theta\sin^2\theta\right\}d\theta$$

$$= a^3\times\frac{7}{2}\pi;$$

$$\therefore \bar{y} = \frac{7}{6}a.$$

(1) The distance of centroid from base $= \frac{5}{6}a$, hence by Pappus's theorem,

$$V \text{ (about base)} = 2\pi\times\frac{5}{6}a\times 3\pi a^2 = 5\pi^2a^3.$$

(2) Volume about axis of y is given by

$$V = \int_0^{\pi a}2\pi(2a-y)\,x\,dx$$

$$= 2\pi a^3\int_0^{\pi}(1+\cos\theta)^2(\theta+\sin\theta)\,d\theta$$

$$= 2\pi a^3\int_0^{\pi}\left\{(1+\cos\theta)^2\sin\theta+\theta+2\theta\cos\theta+\theta\frac{1+\cos 2\theta}{2}\right\}d\theta$$

$$= 2\pi a^3\left[-\frac{(1+\cos\theta)^3}{3}+\frac{3\theta^2}{4}+2(\theta\sin\theta+\cos\theta)+\tfrac{1}{4}(\theta\sin 2\theta+\frac{\cos 2\theta}{2})\right]_0^{\pi}$$

$$= 2\pi a^3\left(\frac{3}{4}\pi^2-\frac{4}{3}\right).$$

(3) The volume about the axis of x is given at once by Pappus's Theorem—

$$V = 2\pi\bar{y}A = 7\pi^2a^3.$$

MOMENT OF INERTIA.—A uniform solid rectangular parallelepiped has its edges 6, 9, and 12 inches long; what is the least time in which it can oscillate about a horizontal axis, and how must the axis be fixed in the body?—(*B.Sc.*, 1904.)

The moment of inertia of solid rectangular parallelepiped of edges a, b, c, about a line through its centre of gravity perpendicular to the face of dimensions $a \times b$, is

$$M\frac{a^2+b^2}{12},$$

where M is the mass of the body. About an axis parallel to this, and distant d from it, the moment of inertia is

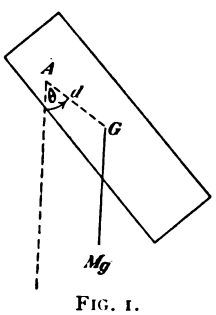

FIG. 1.
MOMENT OF INERTIA.

$$M\left(d^2+\frac{a^2+b^2}{12}\right) \quad . \quad . \quad . \quad (1)$$

Denoting by $\ddot{\theta}$ the common angular acceleration of the particles constituting the body, m the mass of a particle, r its distance from the axis, then the mass-acceleration of the particle is $mr\ddot{\theta}$, its moment about the axis is $mr^2\ddot{\theta}$, and the sum of the moments for all the particles is

$$\ddot{\theta}\Sigma mr^2 = I\ddot{\theta}$$

where I denotes the moment of inertia.

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This sum must equal the moment of the external forces, and hence (see Fig. 1)

$$I\ddot{\theta} = -Mgd\sin\theta;$$

if θ is small, we may take as an approximation

$$I\ddot{\theta} = -Mgd.\theta,$$

the simple harmonic motion equation.

Hence the periodic time is given by

$$T = 2\pi\sqrt{\frac{I}{Mgd}}$$

$$= 2\pi\sqrt{\frac{1}{g}\left(d + \frac{a^2+b^2}{12d}\right)} \quad . \quad . \quad (2)$$

This equation (2) tells us that the time of oscillation is the same about all points distant d from the axis through G, $\perp^r$ to face $a\,b$.

T will be a minimum when

$$d + \frac{a^2+b^2}{12d} \text{ is a minimum,}$$

i.e., when

$$\left(\sqrt{d} - \sqrt{\frac{a^2+b^2}{12}}/\sqrt{d}\right)^2 + 2\sqrt{\frac{a^2+b^2}{12}}$$

is a minimum. Obviously the least value is when the quantity within the brackets is zero, *i.e.*,

$$d^2 = \frac{a^2+b^2}{12}$$

The axis must, therefore, be at a distance from the C.G. equal to the radius of gyration about the axis through the C.G.

In the given case, the minimum value of $\frac{a^2+b^2}{12}$ is $\frac{36+81}{12}$, and hence

$$d = \tfrac{1}{2}\sqrt{39}.$$

The minimum time of oscillation is

$$2\pi\sqrt{\frac{1}{g}\left(\frac{d+d}{12}\right)}$$

$$= 2\pi\sqrt{\frac{\sqrt{39}}{384}}$$

which is approximately 0·8 second.

STRESSES AND STRAINS.—Will you please inform me of the best books dealing with stresses and strains, graphically and by calculation.

"Theory and Practice of Modern Framed Structures," by Johnson Bryan and Turneaure, published by John Wiley and Sons, New York; sold in London by Chapman and Hall, Limited. Price about 2 guineas.

This book deals very thoroughly with stresses and strains. It is full of well-selected examples from existing structures. It deals with the essential problems both analytically and graphically. This book is perhaps the best of the higher-priced books.

"Alexander and Thomson's Applied Mechanics" is a very good book, and is confined largely to Theory of Structures. Price about 25*s*.

"Theory of Structures and Strength of Materials," by Professor Bovey, published by John Wiley and Sons, is a very good book and fairly complete.

"The Application of Graphic Methods to the Design of Structures," by Professor W. W. F. Pullen, published by the Technical Publishing Company, Limited, Manchester. Price 6*s*. net.

This book is in our opinion the best book on the market at its price. The title is to our mind somewhat of a misnomer, as many problems are very lucidly dealt with by purely analytical means. Perhaps we would be fairer to the author if we said that the book contains the application of Graphic Methods to the Design of Structures—and contains much more beside.

"Theory of Strains in Girders and Similar Structures," by Bindon B. Stoney, price about 24*s*., is an excellent book, but perhaps not so modern as the first book on our list. It is published by Longman, Green and Company.

BOAT'S DERRICK.—The sketch (Fig. 1) represents a derrick fitted to a ship's mast for lifting boats. By means of Gordon's or other pillar formulæ, only one diameter can be found, yet these derricks are always made larger at the centre than at the ends. Will you please inform me how the diameter at the various parts can be calculated?

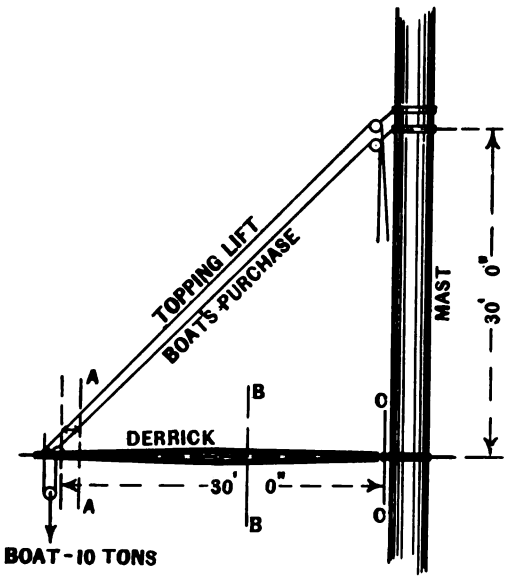

FIG. 1.—BOAT'S DERRICK.

The horizontal strut is to be taken as a pillar with hinged or rounded ends. As it is impossible in practice to ensure that the end forces are absolutely axial, the tendency will be for the strut to deflect as shown in diagram No. 2.

The deflection is of course exaggerated for purposes of illustration, but even if the end forces were mathematically central, the dead weight of the boom would cause it to deflect

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or sag in the middle. It is of course possible for the end forces to be applied in such a position that the tendency to sag would be counteracted by the tendency of the boom to hogback. The chances, however, of such an exact balance are too remote for serious consideration. It will be seen from Fig. 2 that the bending moment will be proportional to x, and therefore as x increases, the cross-sectional area should become greater and greater.

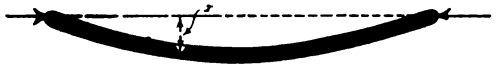

FIG. 2.—BOAT'S DERRICK.

Gordon's pillar formula takes the maximum safe deflection of the pillar into account, and Gordon's equations give us the requisite diameter of round-ended pillars at the middle of their length.

It will be seen that the value of x at the end of the pillar = 0, therefore the bending moment will be zero. Consequently the ends of the pillar need only be designed to carry the maximum direct compressive stress without reference to any bending or pillar formulæ.

As the end fittings of the boom may reduce the cross-sectional area at the ends, perhaps by as much as 50 or 60 per cent., it is not advisable to determine the area of the end of the strut without a careful examination of the proposed end fittings. Care should also be taken that the end fittings are not such as will cause a bending moment at the extremities of the pillar.

The contour or profile of the strut may be a flat circular arc or a parabola drawn so that the diameters of the strut at the ends and centre fulfil the aforementioned conditions (see Fig. 3).

FIG. 3.—BOAT'S DERRICK.

As the topping lift makes an angle of about 45° with the centre line of the derrick, the triangle of forces will show that the load on the strut will be equal to the total load of the boat and its contents, *viz.*, 10 tons.

If the boat is being lifted from the water, the waves may sink from under the boat and bring the load suddenly on the lifting gear, therefore the ten tons should be treated as a live load, and an equivalent dead load of 20 tons taken in the calculation; or, alternatively the factor of safety should be doubled to allow for the live load effect.

HAULAGE.—A load of 100 tons has to be hauled up an incline of 1 in 6, the haulage ropes and tubs having to pass round a curve of 80-ft. radius in their journey. If the rope is guided round the curve by means of three pulleys (3-ft. diameter, arc of contact of rope on each pulley 20°, diameter of pulley spindle 3 in., coefficient of friction between rope and pulley 0·1, between tubs and rail 0·02), find the maximum pull required to move the above load at a velocity of 10 miles per hour, taking into account acceleration. The load to start from rest and get up speed in 1 minute. The total angle passed through by curve is 75°, rope 1¼-in. diameter, friction in spindle journals 0·008.

With a slope of 1 in 6, the ratio of the height to hypothenuse is 1 to 6·1, and consequently the pull along the incline necessary to overcome gravity only must be $\frac{1}{6\cdot1}$ of the load, or 16·4 tons. The length of the rope is not given; but, assuming the length of slope to be 500 ft., its weight would be about a ton.

The arc of contact of the rope and each guide pulley is given as 20°, but if there are three of them, and the total angle of deviation is 75°, the angle of contact must be 25°. If P is the pull in the rope, then the pressure on a wheel spindle must be $2P \sin 12\cdot5° = 0\cdot43P$. The resistance of friction at the surface of the bearing is $\mu \times 0\cdot43P$ or $0\cdot008 \times 0\cdot43P$, and the equivalent of this along the axis of the rope is $\frac{1\cdot5}{18} \times 0\cdot008 \times 0\cdot43P$. There are three pulleys, and hence the total resistance due to pulley friction measured along the rope's axis is $0\cdot00087P$, a quantity too small to be compared with P, and hence may be neglected.

The rope will run on rollers, which will offer some resistance, but, as no data are given, this will be neglected also. The tub friction is $0\cdot02 \times 100 = 2$ tons.

The pull required to produce the acceleration only is given by the fundamental equation:—

$$g \times \text{force} \times \text{time of action} = \text{total change of momentum},$$

or $$32 \times \text{force} \times 60 = 100 \times \frac{88}{6};$$

that is, force = 0·8 ton (approximately).

Pull required to lift the rope is

$$\frac{1}{6\cdot1} \text{ of } 1 = 0\cdot3 \text{ ton.}$$

The total pull in the rope is then

$$16\cdot4 + 0\cdot3 + 0\cdot8 + 2 = 19\cdot5 \text{ tons.}$$

The effect of the guide pulleys, as shown above, is quite negligible.

DOME.—I beg to forward a drawing of a dome. The shell is to be constructed of blue trapstones with a backing of brick and lime mortar. It is required to ascertain the stresses which will be produced in the different parts. It is requested that a stress diagram may be given.

We are of opinion that the dome would be more satisfactory if executed in cement mortar. "The setting of lime mortar depends upon the absorption of carbon dioxide from the atmosphere. Pure lime mortar, built in thick walls, never hardens or sets, but crumbles into a friable powder. For this reason pure limes should be avoided for constructional work," and a mortar which does not depend upon contact with the air for the development of its setting and

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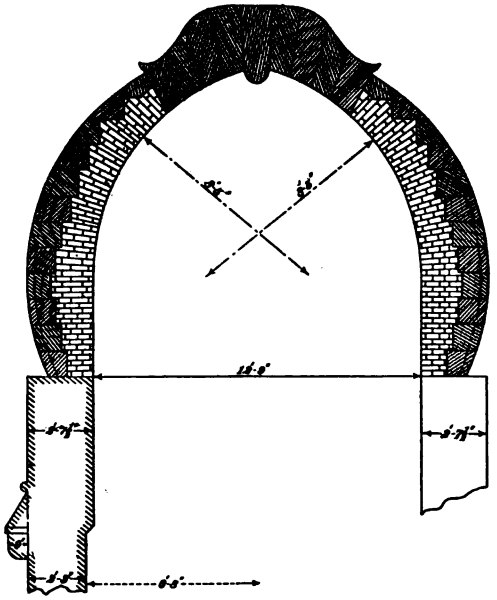

FIG. 1.—DOME.

hardening properties, should be used instead (*vide* "Building Construction, Advanced Course." By Chas. F. Mitchell).

For the purpose of facilitating the calculations, we can safely assume a mean weight per cubic foot for a compound of trap rock and brickwork.

We shall take the combined weight at 145 lbs. per cubic foot. Professor Rankine's Chapter on "Domes" in his "Applied Mechanics" will be found very instructive. Rankine's method is, however, not adapted for supplying the stress diagram you require.

In Fig. 2 we have shown the half section and the plan of a segment of the dome. It will be observed that the portion of the dome below the level of the line of the centres of the radii is not considered. This is because the dome proper commences from this point, the portion below being known as the "drum."

To arrive at the stresses in the different parts, we consider a segment of the shape shown in plan, which for convenience has been taken with a minimum width of one foot. We next split the section up into a number of parts. These parts are lettered A, B, C, etc., and the weights are given on drawing as follows :—

A =	·22 cwts.	F =	1·44 cwts.
B =	·65 „	G =	1·83 „
C =	1·27 „	H =	2·16 „
D =	1·41 „	J =	2·30 „
E =	1·51 „	K =	2·70 „
		L =	2·72 cwts.

which add up to a total of 18·21 cwts. for the whole segment.

These loads are set down on the load line in polar diagram.

The centre of gravity of these loads is arrived at graphically by means of the funicular polygon, shown by dotted lines, and is found to be on a line at 2 feet 3½ inches away from the centre of the wall of dome.

The centre of pressure at apex of dome is assumed to coincide with centre of wall or ceiling at apex, and is found to be 9 feet 4 inches above line of springing.

Now we have the following conditions for equilibrium :—

$$T \times 9{\cdot}33 \text{ feet} = 18{\cdot}21 \text{ cwt.} \times 2{\cdot}29 \text{ feet},$$

$$\therefore\ T = \frac{18{\cdot}21 \text{ cwt.} \times 2{\cdot}29 \text{ feet}}{9{\cdot}33 \text{ feet}}$$

$$= 4{\cdot}5 \text{ cwt. thrust at apex.}$$

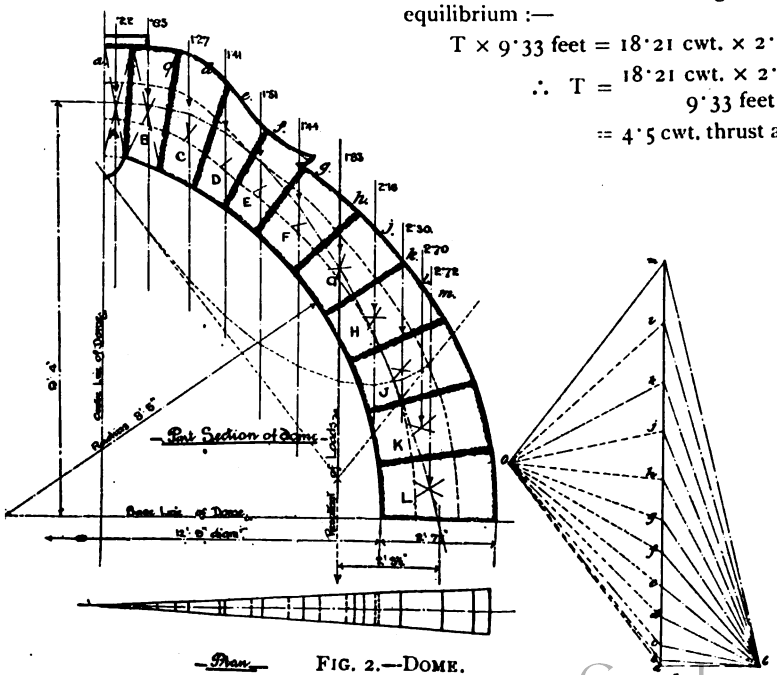

FIG. 2.—DOME.

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The line of resistance is shown by a chain line, and is obtained from diagram to the right of load line.

It is suggested that the dome would be better if the joints were perpendicular to the line of thrust.

HYDROMECHANICS.—A mass m of elastic fluid is rotating about an axis with uniform angular velocity ω, and is acted on by an attraction towards a point in that axis equal to μ times the distance, μ being greater than ω^2; prove that the equation of a surface of equal density ρ is

$$\mu(x^2+y^2+z^2) - \omega^2(x^2+y^2) = k \log\left\{\frac{\mu(\mu-\omega^2)^2}{8\pi^3}\cdot\frac{m^2}{\rho^2 k^3}\right\}.$$

(*Besant's Hydromechanics*, page 39.)

Starting with the well-known equation

$$dp = \rho(X\,dx + Y\,dy + Z\,dz)$$

we have for an elastic fluid

$$p = k\rho.$$

Taking the origin of co-ordinates at the centre of attraction, the force per unit of mass, due to the attraction, is given by

$$\mu\sqrt{(x^2+y^2+z^2)} = \mu R \text{ (say)},$$

of which the rectangular components are

$$\mu R\cdot\frac{x}{R},\quad \mu R\,\frac{y}{R},\quad \mu R\,\frac{z}{R}$$

directed *towards* the centre of force.

Taking the axis of z as the axis of rotation, we have an acceleration, *viz.*, $\omega^2\sqrt{(x^2+y^2)}$, directed towards the axis. If $x^2+y^2=r^2$, this is $\omega^2 r$, and its components are $\omega^2 x$ and $\omega^2 y$.

A force equal to this, but reversed in sign, together with the attraction and pressure, form a set of forces in equilibrium.

Hence
$$X = \omega^2 x - \mu x$$
$$Y = \omega^2 y - \mu y$$
$$Z = \quad -\mu z,$$

and

$$dp = -\frac{p}{k}\{(\mu-\omega^2)(x\,dx+y\,dy)+\mu z\,dz\}.$$

Integrating, we obtain

$$k\log\frac{C}{p} = \tfrac{1}{2}\{(\mu-\omega^2)(x^2+y^2)+\mu z^2\} \quad . \quad . \quad . \quad (1)$$

where k log C is the constant of integration. Putting in exponentials, we have

$$\frac{C^2}{p^2} = \epsilon^{\frac{(\mu-\omega^2)r^2+\mu z^2}{k}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

We see from (1) that the surfaces of equal pressure are ellipsoids of revolutions, and hence when $p=0$ (free surface) we have x, y, and z all infinitely large.

The constant C is determined from the known mass m of the fluid. We know that all points having equal values of r and z have the same density ρ, hence

$$m = \int_0^\infty\int_0^\infty 2\pi r\rho\,dr\,dz$$

from (2) $\quad \frac{C^2}{k^2\rho^2} = \epsilon^{\frac{(\mu-\omega^2)r^2+\mu z^2}{k}}$;

$$\therefore m = \frac{2\pi C}{k}\int_0^\infty\int_0^\infty r\,\epsilon^{-\frac{(\mu-\omega^2)r^2+\mu z^2}{2k}}\,dr\,dz$$

$$= \frac{2\pi C}{k}\int_0^\infty \frac{k}{\mu-\omega^2}\left[-\epsilon^{\frac{-(\mu-\omega^2)r^2}{2k}}\right]_0^\infty \epsilon^{-\frac{\mu z^2}{2k}}\,dz$$

$$= \frac{2\pi C}{(\mu-\omega^2)}\int_0^\infty \epsilon^{-\frac{\mu z^2}{2k}}\,dz$$

$$= \frac{2\pi C}{(\mu-\omega^2)}\cdot\frac{\sqrt{\pi}}{\sqrt{\frac{\mu}{2k}}}$$

Hence $C^2 = \dfrac{m^2(\mu-\omega^2)^2\mu}{8\pi^3 k}$

and finally, on substitution in (1)

$$\mu(x^2+y^2+z^2) - \omega^2(x^2+y^2) = k\log\left\{\frac{\mu(\mu-\omega^2)^2}{8\pi^3}\cdot\frac{m^2}{\rho^2 k^3}\right\}.$$

HYPOCYCLOID.—A method of finding cusps on plane curves is to solve simultaneously the equations

$$\frac{\partial\phi}{\partial x} = 0,\ \frac{\partial\phi}{\partial y} = 0, \text{ and } \phi(x,y) = 0.$$

Why does this method fail in the case of the four-cusped hypocycloid

$$x^{\frac{2}{3}} + y^{\frac{2}{3}} = a^{\frac{2}{3}}\ ?$$

The general theory for the *Tests* for double points on plane curves is built up on the assumption that the equation to the curve can be put in the form

$$A_0 + (A_1 x + B_1 y) + (A_2 x^2 + B_2 y^2 + B x y) + \ldots = 0,$$

and it is only allowable to apply these tests when the equation *is* of this form.

Now the given equation can be put in form

$$x^2 = a^2 - y^2 - 3a^{\frac{4}{3}}y^{\frac{2}{3}} + 3a^{\frac{2}{3}}y^{\frac{4}{3}}$$

$$\therefore x^2+y^2-a^2 = 3a^{\frac{2}{3}}y^{\frac{2}{3}}(y^{\frac{2}{3}} - a^{\frac{2}{3}})$$

$$= -3a^{\frac{2}{3}}x^{\frac{2}{3}}y^{\frac{2}{3}}.$$

$$\therefore (x^2+y^2-a^2)^3 = -27a^2x^2y^2.$$

Hence $\dfrac{\partial\phi}{\partial x} = 3(x^2+y^2-a^2)^2 + 54a^2xy^2 = 0$

$$\frac{\partial\phi}{\partial y} = 3(x^2+y^2-a^2)^2 + 54a^2x^2y = 0$$

$x = 0, y = \pm a$, and $y = 0, x = \pm a$

satisfy these equations and also the equation to the curve.

The points so determined are therefore double points. To decide whether they are nodes, cusps, or conjugate points, we must either trace the curve in the neighbourhood of these points, or apply a further test for a cusp

$$\left(\frac{\partial^2\phi}{\partial x\,\partial y}\right)^2 = \frac{\partial^2\phi}{\partial x^2}\cdot\frac{\partial^2\phi}{\partial y^2}.$$

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THEORETICAL MECHANICS.—Three particles of equal masses are attached at equal intervals to a string of negligible mass. The middle particle is held at a point A of a smooth horizontal plane, and the other two describe the same circle about it in the same sense and with the same uniform speed, so that the line joining them subtends an angle α at the point A. Prove that, if the middle particle is let go, the tension of either part of the string is suddenly diminished in the ratio 1 : (2 + cos α).— *Entrance Scholarship, St. John's College, Cambridge.*

Before A is let go, the tension in each half of the string is $(mv^2)/r$, where m = mass and v = velocity of each particle, and r is the radius of the circle. The reaction at A on the string is therefore

$$2\,\frac{mv^2}{r}\cos\,\frac{\alpha}{2}$$

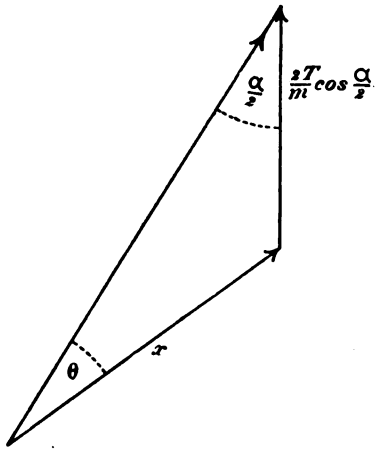

FIG. 1.—THEORETICAL MECHANICS.

and its direction bisects the angle between the two parts of the string. On taking away this force, the particle at A will therefore *begin* to move in this line, and the tension in the two halves of the string will be progressively diminished. Suppose T the new tension, then A will *begin* to move along the bisector with an acceleration

$$2\,\frac{\mathrm{T}}{m}\cos\,\frac{a}{2}.$$

If now we give to both the particles and to A an acceleration

$$-\,\frac{2\mathrm{T}}{m}\cos\,\frac{a}{2}$$

along the bisector, the acceleration of each particle relative to A will be as before, *viz.* (v^2/r) towards A.

If x denote the new acceleration of one of the particles and θ the angle it makes with the string, we see at once from the triangle of accelerations that

$$x\cos\theta = \frac{v^2}{r} - \frac{2\mathrm{T}}{m}\cos\,\frac{2a}{2}.$$

But $x\cos\theta$ is the acceleration along the normal, and therefore the new tension along the string is

$$mx\cos\theta = \frac{mv^2}{r} - 2\mathrm{T}\cos\,\frac{2a}{2} = \mathrm{T};$$

$$\therefore\quad \frac{mv^2}{r} = \mathrm{T}\left(1 + 2\cos\,\frac{2a}{2}\right)$$

$$= \mathrm{T}\,(2 + \cos a).$$

TORPEDO BOAT.—A torpedo boat is to be lifted by means of two slings. If the disposition of weights on board be such that the load per foot run over the central half of the boat's length be uniformly one and a half times that per foot run over the rest of the length, find the best positions for the slings in order that the bending moment on the hull should be the least possible.

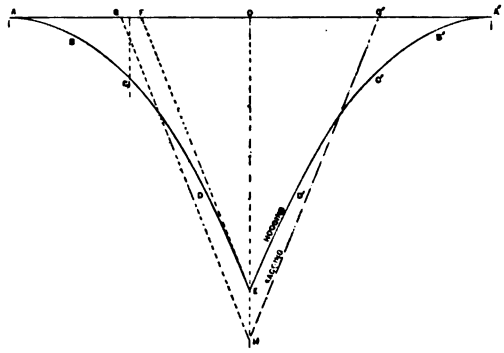

FIG. 1.—TORPEDO BOAT.

Wherever the points of support of the slings are, the bending moment *due to the weight* will be the same, just as if the boat were suspended at the centre. The distribution of this bending moment is shown by the curved line ABCDE · · · · Taking, for convenience, the length of boat as 80 feet and distribution of load at ends 1 ton per foot, and along middle $1\frac{1}{2}$ tons per foot: the bending moment due to weight is 900 ton-feet at centre, and the total weight of boat 100 tons. Each sling therefore takes 50 tons. Now the bending moment due to sling will depend on the position of sling. If at 900/50 = 18 feet from centre, the B.M. curve will be the line EF. In this case the hogging moment at centre due to weight is equal to sagging moment due to support, but at F there is a hogging moment of 243 ton-feet. If the support be shifted along towards the centre there will be an increasing hogging moment at support due to the weight. If the support be shifted towards the ends we shall get a sagging moment in excess at the middle and a hogging moment at support. Where these are equal the maximum sagging moment and hogging moment will be equal, and this will give the point required. If x be this distance from centre the excess sagging moment at centre is $(50 \times x - 900)$. The hogging moment at support is

$$20\,(30 - x) + \frac{1{\cdot}5}{2}\,(20 - x)^2.$$

We therefore equate, and find x · = 21·3 *i.e.*, at 21·3/80 = 0·266 the length, from centre. This may be confirmed by drawing in the bending

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moment line due to support at this point GHG¹. The bending moment on the boat is then the intercept between that due to weight and that due to supports. The ends for $\frac{5}{16}$ length at each end will be subject to a hogging moment and the middle $\frac{3}{8}$ to a sagging moment. The maximum sagging moment is equal to the maximum hogging moment, and any other positions for points of suspension will give rise to a bending moment greater than either of these.

DEFINITE INTEGRAL.—Prove that

$$\int_0^\infty \frac{e^{bx} + e^{-bx}}{e^{\pi x} - e^{-\pi x}} \sin ax \, dx = \tfrac{1}{2} \frac{e^a - e^{-a}}{e^a + 2\cos b + e^{-a}}$$

(*Williamson's Integral Calculus, page* 143.)

It is proved on page 142 that

$$\int_0^\infty \frac{e^{ix} - e^{ix}}{e^{\pi x} - e^{\pi x}} \, dx = \tfrac{1}{2} \tan \frac{b}{2}.$$

Now $(e^{bx} + e^{-bx})(e^{ax} - e^{-ax})$

$= e^{(a+b)x} - e^{-(a+b)x} + e^{(a-b)} - e^{-(a-b)x}$.

Hence,

$$\int_0^\infty \frac{(e^{bx} + e^{-bx})(e^{ax} - e^{-ax})}{e^{\pi x} - e^{-\pi x}} \, dx$$

$$= \tfrac{1}{2} \tan \frac{a+b}{2} + \tfrac{1}{2} \tan \frac{a-b}{2}$$

$$= \frac{\sin a}{\cos a + \cos b}.$$

If $i = \sqrt{-1}$, then

$$\int_0^\infty \frac{e^{bx} + e^{-bx}}{e^{\pi x} - e^{-\pi x}} \sin ax \, dx$$

$$= \frac{1}{2i} \int_0^\infty \frac{(e^{bx} + e^{-bx})(e^{iax} - e^{-iax})}{e^{\pi x} - e^{-x}} \, dx$$

$$= \frac{1}{2i} \frac{\sin ia}{\cos ia + \cos b} \quad \text{(by the foregoing)}$$

$$= \frac{1}{2i} \frac{e^{-a} - e^{a}}{2i} + \left(\frac{e^{-a} + e^{a}}{2} + \cos b\right)$$

$$= \frac{1}{2} \frac{e^{a} - e^{-a}}{e^{a} + 2\cos b + e^{-a}}$$

BIBLIOGRAPHY.—Would you kindly recommend me the best books in French on naval architecture,

The books in French known to the writer are "Théorie du Navire," Pollard and Dudebout; "Théorie du Navire," Clauzel. The former is in four volumes and is a most exhaustive work, dealing with the whole range of theoretical naval architecture. The latter is in two volumes text and plates, and is more adapted for the average student.

As regards Applied Mechanics, the writer has always used Professor Cotterill's (large) Applied Mechanics, which grew out of lectures to naval constructors and engineers at the Royal Naval College, Greenwich. It is written in a very clear manner and I fancy would be hard to better.

GRAPHICAL STATICS.—Please inform me of the best books on (1) Graphical Statics; (2) Worked Examples on Rigid Dynamics and Analytical Statics; (3) Examples in Physics of the B.Sc. Pass and Honours Standard, with hints for solution.

(1) Cremona's Graphical Statics, translated by Professor Hudson Beare (Clarendon Press); The Elements of Graphic Statics, by L. M. Hoskins (Macmillan), intended for engineers. The subject is also treated by aid of vectors in Professor Henrici's little book, "Vectors and Rotors" (Arnold, 4*s.* 6*d.*).

(2) Many worked examples will be found in such text-books as Love's Mechanics, Besant's Dynamics, Minchin's Statics, etc., and also in Wolstenholme's Mathematical Problems. Besides these there are a number of volumes of Solutions of Senate House Mathematical Problems, by such men as Dr. Routh.

(3) No such collection of examples has been published in England.

Several Answers to Queries have been unavoidably held over; these will be published next month.

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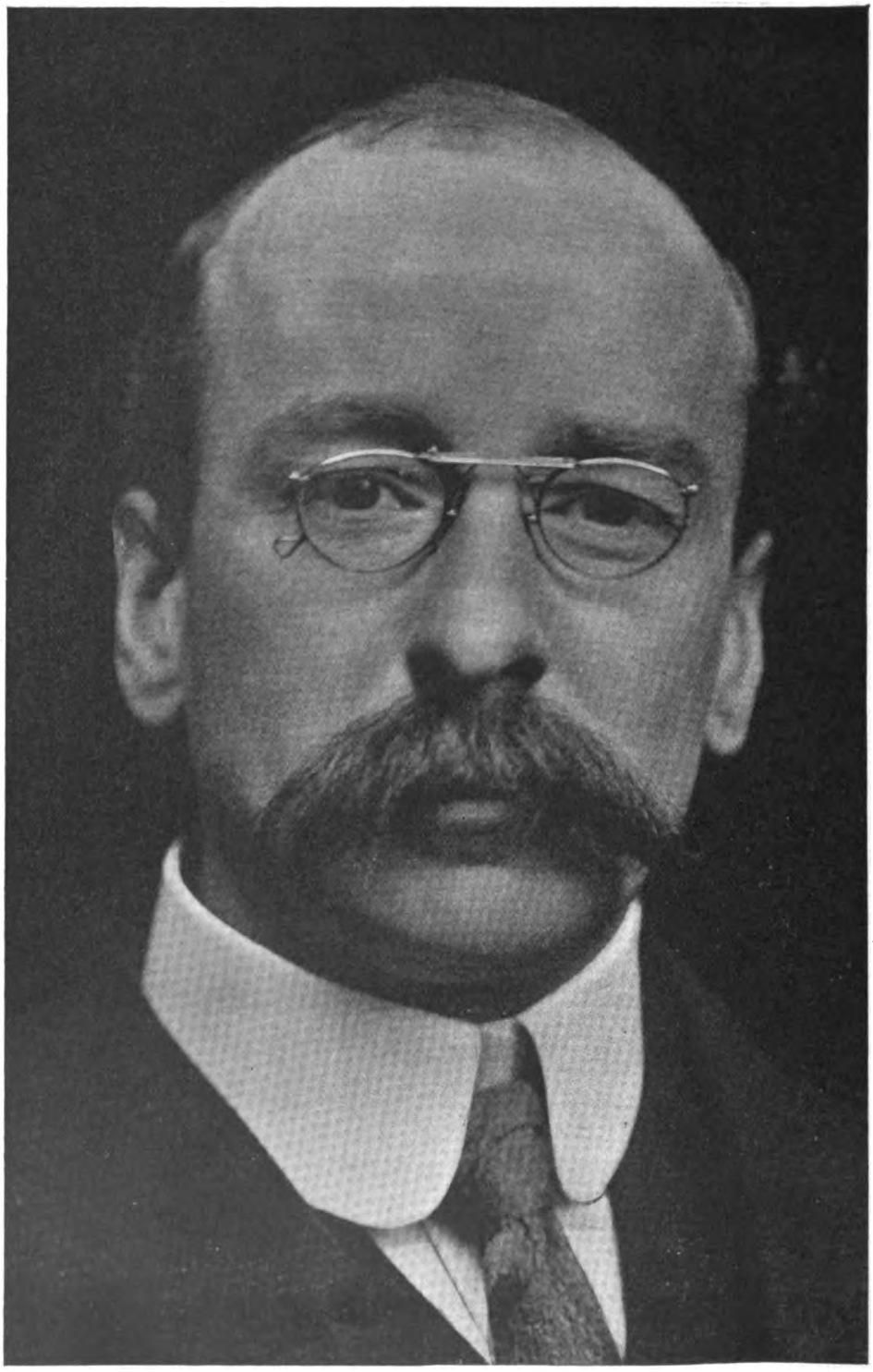

DAVID SING CAPPER, M.A., M.Inst.C.E., M.I.Mech.E., M.I.E.E.

Reporter to the Steam Engine Research Committee.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. III. MAY, 1905. No. 17.

PROGRESS OF SCIENCE AND TECHNOLOGY.

ENGINEERS cannot but feel grateful for the vast amount of experimental data placed at their disposal by the Steam-Engine Research Committee. This committee was formed nine years ago, and at that time consisted of Professors Kennedy and Capper, Messrs. Bryan Donkin, Michael Longridge, J. Mair-Rumley, and E. Windsor Richards; at present it consists of Mr. W. H. Maw (chairman), Professor Capper (reporter), Professor Kennedy, Captain Sankey, and Messrs. Henry Davey, Michael Longridge, and J. Mair-Rumley. The report of the committee was read on March 17th by Professor Capper; the following are the general conclusions arrived at:—

Steam-Engine Research

"It is dangerous to draw conclusions of too general and sweeping a character from experiments upon one type of engine under one set of conditions; but it may fairly be claimed that the ground covered by this report has never previously been surveyed with an engine showing more consistent and definite results, nor under conditions which enabled so detailed an analysis of the results to be made. It may, therefore, be anticipated with some confidence that the definite indications shown by the results form a real contribution to the present knowledge of the phenomena accompanying condensation and re-evaporation in an engine cylinder under given conditions of jacketing. The points which have been elucidated may be summarised as follows:—

"*Firstly*, leakage through the slide-valve—to the importance of which Messrs. Callendar and Nicolson have drawn attention—has been quantitatively determined under defined conditions, and has been shown to be nearly independent of speed of sliding surface and proportional to difference of pressure between the two sides of the valve. Further, it has been shown that the assumption that the leakage is inversely as the overlap of the valve is, at least in the main, well founded; and, further, that with well-fitted valves the leakage may amount to over twenty per cent. of the steam entering the cylinder, and is rarely less than four per cent.

"*Secondly*, it has been shown that for an unjacketed engine with a given ratio of expansion, initial condensation, expressed as a percentage of the steam in the cylinder, *diminishes* with increase of initial temperature, while the total condensation per stroke *increases* with such temperature increase This, though suggested by Messrs. Callendar and Nicolson's researches, has never previously been demonstrated with clearness; as if leakage is not allowed for, the results are obscured and even reversed, and the conclusions arrived at without leakage allowance are therefore untrustworthy.

"*Thirdly*, it appears from the results here obtained that the re-evaporation for a given ratio of expansion is as great, and sometimes greater, without jackets than with them. This shows very clearly that the regenerative action of the cylinder walls, with a given ratio of expansion, is largely independent of their mean temperature. No quantitative analysis of re-evaporation is possible where leakage is not taken into account, as without the necessary allowance results would be largely illusory.

"*Fourthly*, it is possible from the results obtained to show the temperature at which, for any speed of revolution with a given rate of expansion, the jackets will become unnecessary or wasteful. If the heat units per indicated horse-power per minute required by the unjacketed engine for each speed of the series be plotted either on an initial pressure or a mean effective pressure base, the points for each speed will be found to lie on four curves, which become closer and closer to one another as the speed increases, and all converge to a point as pressure or temperature

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increases. If the heat consumption for the jacketed series be likewise plotted, it will be found that the points for the different speeds at each pressure lie irregularly round a point, their exact position being determined by the accidentally slight variations of the conditions of each trial. A fair curve through the means of these points will lie below the corresponding curves for the unjacketed trials; but if the heat absorbed in the jackets be included, the resultant curve cuts the unjacketed curves at points which, for each speed, indicate the temperature and pressure at which the jackets cease to be economical."

In the discussion which followed the reading of the report, Mr. Longridge said that, in his opinion, the leakage is not proportional to the difference of pressure, but to the square root of the difference of pressure. He pointed out that this is what might be anticipated from considering steam (whether saturated or superheated) as a fluid; in fluid motion the velocity of flow is proportional to the square root of the "head." The curves published in the report confirmed this view.

Importance of Leakage

As to the importance of leakage in connection with steam-engine design, the following remarks made by Professor Burstall, and reported in *Engineering* of April 7th, are of great interest:—

"He wished to refer to the question of leakage through valves. The last speaker had asked how far this matter influenced the design of engines; he (Professor Burstall) would say that it meant everything. Both the report and the paper by Messrs. Callendar and Nicolson showed that all valves leaked, whether they were slide-valves, Corliss valves —although this was not admitted—or double-beat valves, such as were used in Sulzer and Cornish engines. If there were a definite law of valve-leakage, it was evidently of importance to know it, for it would help the designer of engines very considerably. He was afraid that the experiments detailed in the report, and those of Messrs. Callendar and Nicolson, did not prove that there was a definite law of valve-leakage, showing that that leakage was proportional to the difference of pressure or to the overlap. He had plotted the leakage against the pressures as given in the paper, and as against the temperatures, and he found that when the valve-leak was plotted against the difference of temperature between the valve-chest and the exhaust, the points were in a straight line. He did not suppose this was universal, but it corresponded with the records in the paper. The number of experiments, however, was not sufficient to determine a law; an immense number of experiments would be required before a law of valve-leakage could be stated. It was, however, well worth considering what would be the consequence if the leakage were proportional to the difference of temperature between the valve-chest and the exhaust. This would rather point to the leak being due to a distorted valve. Experiments with D valves, worked with saturated and with superheated steam, showed that when the flat valves were taken out and tested for truth, after experiments with superheat, they were invariably warped. If warping took place with superheat, and was apparent when the valve became cold, why, he asked, should it be denied that it was possible that the valve warped, and returned to its shape when it became cold, even when dealing with superheated steam? He thought that Captain Sankey's experiments distinctly showed that the warped valve was the cause of leakage. These interesting experiments were made with a Willans engine and spring rings, and if there was one form less susceptible to warping than another, it was a purely circular form. The D valve was a more or less complex casting, in which there were initial stresses which might or might not be released by the action of the steam; with the spring ring there was none of this. Captain Sankey's experiments tended to show that the spring ring gave a very much smaller coefficient—0·003 as against 0·21 in the case of the flat valves. It would not do to carry these things too far, for it might be asked how it was that engines with flat valves did as well, or even better, than those with piston valves. The whole of the results as to valve-leakage showed most distinctly that engines will do equally well with any kind of valve."

High-Speed Steel

A VALUABLE paper, communicated by Mr. J. M. Gledhill to the Iron and Steel Institute, New York, in October last, contains the following interesting particulars relative to the effects of various elements on high-speed steel:—

"The high-speed steels of the present day are combinations of iron and carbon, with (1) tungsten and chromium, (2) molybdenum and chromium, (3) tungsten, molybdenum and chromium. These present many interesting varieties, and offer a wide field for research. The author has made a large number of experiments to ascertain comparative cutting powers of steels produced by varying pro-

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portions of these elements, and it may be interesting to briefly state the results of some of these investigations.

"*Influence of Carbon.*—A number of tool steels were made, the carbon percentage varying from 0·4 per cent. to 2·2 per cent., and the method of hardening was to heat the steel to the highest possible temperature without destroying the cutting edge, and then rapidly cooling in a strong air blast. By this simple method of hardening it was found that the greatest cutting efficiency is obtained where the carbon ranges from 0·4 per cent. to 0·9 per cent., and such steels are comparatively tough. Higher percentages are not desirable, because great difficulty is experienced in forging the steels, and the tools are inferior. With increased carbon content the steel is also very brittle, and has a tendency to break with unequal and intermittent cutting.

"*Influence of Chromium.*—Having thus found the best carbon content to range from 0·4 per cent. to 0·9 per cent., the next experiments were made to ascertain the influence of chromium varying from 1·0 per cent. to 6·0 per cent. Steels containing a low percentage are very tough, and perform excellent work on the softer varieties of steel and cast iron; but when tried on harder materials the results obtained were not so efficient. With an increased content of chromium the nature of the steel becomes much harder, and greater cutting efficiency is obtained on hard materials. It was observed that with an increase of chromium there must be a decrease in carbon to obtain the best results.

"Mention may here be made of an interesting experiment to ascertain what effect would be produced in a rapid steel by substituting vanadium for chromium. The amount of vanadium present was 2·0 per cent. The steel readily forged, worked very tough, and was hardened by heating to a white heat and cooling in an air blast. This tool, when tried on medium steel, stood well, but not better than the steel with the much cheaper element, chromium, in it.

"*Influence of Tungsten.*—This important element is contained in by far the greater number of the present high-speed steels in use. A number of experiments were made with tungsten contents, ranging from 9·0 per cent. to 27·0 per cent. From 9·0 per cent. to 10·6 per cent. the nature of the steel becomes very brittle, but at the same time the cutting efficiency is greatly increased, and about 16·0 per cent. appeared to be the limit, as no better results were obtained by increasing the tungsten beyond this figure. Between 18·0 per cent. and 27·0 per cent. it was found that the nature of the steel altered somewhat, and, instead of being brittle, it became softer and tougher; whilst such tools have the property of cutting very cleanly, they do not stand up so well.

"*Influence of Molybdenum.*—The influence of this element at the present time is under investigation, and our experiments with it have so far produced excellent results, and it is found that where a large percentage of tungsten is necessary to make a good rapid steel, a considerably less percentage of molybdenum will suffice. A peculiarity of these molybdenum steels is that, in order to obtain the greatest efficiency, they do not require such a high temperature in hardening as do the tungsten steels, and if the temperature is increased above 1000° C. the tools are inferior, and the life shortened.

"*Influence of Tungsten with Molybdenum.*—It was found that the presence of from 0·5 per cent. to 3·0 per cent. molybdenum in a high tungsten steel slightly increased the cutting efficiency, but the advantage gained is altogether out of proportion to the cost of the added molybdenum.

"*Influence of Silicon.*—A number of rapid steels were made with silicon content varying from a trace up to 4·0 per cent. Silicon sensibly hardens such steels, and the cutting efficiency on hard materials is increased by additions up to 3·0 per cent. By increasing the silicon above 3·0 per cent., however, the cutting efficiency begins to decline. Various experiments were made with other metals as alloys, but the results obtained were not sufficiently good, in comparison with the above, to call for comment."

An analysis of one of the best qualities of rapid steels produced by the author's firm is as follows:—

"A. W. STEEL."

Carbon . . .	0·55 per cent.
Chromium . .	3·5 per cent.
Tungsten . . .	13·5 per cent.

Hardening and Tempering High-Speed Tools

MR. GLEDHILL gives some interesting information as to electrical methods of hardening and tempering high-speed tools. In one of these the point of the tool to be hardened is gradually lowered into a strong solution of potassium carbonate, contained in a cast-iron tank. The tank is connected to the negative terminal of a shunt-wound dynamo, of which the positive terminal is connected by a flexible cable to the tool to be hardened. Contact between

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the tool and the solution completes the circuit of the dynamo, and the immersed part of the tool rapidly becomes intensely hot; we presume the liquid near the tool assumes the spheroidal state, so that an arc is practically formed between the liquid and the point of the tool immersed in it. The tip of the tool should be heated very nearly to the melting point of the steel; on the switching off the current the solution chills and hardens the tool. It has been found best to regulate the voltage of the dynamo by means of a rheostat included in the shunt circuit.

In another method an arc is formed between a carbon rod (which acts as the negative electrode) and the point of the tool to be hardened (which acts as the positive electrode). The arc is started at a low voltage; the voltage is then gradually increased by switching resistance out of the shunt circuit of the dynamo. In this case it was found best to use a shunt-wound dynamo, working at from 50 to 150 volts, and from 10 to 1,000 amperes; this was coupled direct to a 220-volt motor.

It frequently happens that hollow tools (such as milling, gear, hobbing, and other similar cutters) are required to be tempered in such a manner that the outside surface remains hard, while the interior is rendered soft and tenacious. This end is sometimes attained by inserting a heated rod within the hollow tool, and withdrawing this when the film of oxide on the outside surface indicates that the requisite temperature has been reached. This method has the disadvantage that the tool is likely to be cracked by being heated too suddenly, and, therefore, an electrical method has been adopted.

An iron mandrel is inserted within the hollow tool, and the ends of this mandrel are connected to the extremities of a loop of thick copper, which forms the secondary of a step-down transformer, of which the primary is connected to the mains of an alternating dynamo (350 volts, 100 amperes, 50 cycles per second); the voltage in the secondary circuit amounts only to 2 volts. The specific resistance of iron being high, on comparison with that of copper, nearly the whole fall of potential in the secondary circuit occurs in the iron mandrel, which thus becomes heated. The temperature of the mandrel can be gradually increased by varying the exciting current of the dynamo; when the film of oxide on the outside surface of the tool acquires the proper shade, the transformer is switched out of circuit.

Portland Cement

THE properties and methods of mixing Portland cement were described by Mr. Brysson Cunningham in the February number of TECHNICS (pp. 171–176). Since that article was written the Engineering Standards Committee have issued their Specifications for Portland Cement.* To a great extent the publication covers the same ground as that covered in Mr. Cunningham's article. With relation to chemical composition, it is prescribed that "there shall be no excess of lime—that is to say, the proportion of lime shall be not greater than is necessary to saturate the silica and alumina present. The percentage of insoluble residue shall not exceed 1·5 per cent.; that of magnesia shall not exceed 3 per cent.; and that of sulphuric anhydride shall not exceed 2·5 per cent."

The methods of testing prescribed are as follows:—

"Briquettes of neat cement of the shape prescribed shall be gauged for breaking at 7 and 28 days respectively, six briquettes for each period. The average tensile strength of the six briquettes shall be taken as the accepted tensile strength for each period. For breaking, the briquettes shall be held in strong metal jaws, of the shape shown, the briquettes being slightly greased where gripped by the jaws. The load must then be steadily and uniformly applied, starting from zero, increasing at the rate of 100 lb. in 12 seconds. The briquettes shall bear on the average not less than the following tensile stresses before breaking:—

"Seven days from gauging, 400 lb. per square inch of section.

"Twenty-eight days from gauging, 500 lb. per square inch of section.

"The increase from 7 to 28 days shall not be less than:—

"Twenty-five per cent. when the 7-day test falls between 400 lb. to 450 lb. per square inch of section.

"Twenty per cent. when the 7-day test falls between 450 lb. to 500 lb. per square inch of section.

"Fifteen per cent. when the 7-day test falls between 500 lb. to 550 lb. per square inch of section.

"Ten per cent. when the 7-day test is 550 lb. per square inch or upward.

"*Sand Test.*—The cement shall also be tested by means of briquettes prepared from one part of cement to three parts by weight

* British Specification for Portland Cement. (London: Crosby, Lockwood & Son.) Price 2*s.* 6*d.* net.

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of dry standard sand. The proportion of water used shall be such that the mixture is thoroughly wetted, and there shall be no superfluous water when the briquettes are formed. The cement and sand briquettes shall bear the following tensile stresses :—

"Seven days from gauging, 120 lb. per square inch of section.

"Twenty-eight days from gauging, 225 lb. per square inch of section.

"The increase from 7 to 28 days shall not be less than 20 per cent."

Refractory Furnace Linings

THE recent paper and discussion upon *Fuel Economy in Steam Power Plants* at the Institute of Electrical Engineers, raised some interesting questions relating to the use of refractory materials for lining the combustion chambers of boiler furnaces. The authors of the paper had advocated an increase in the temperature of combustion, by means of refractory linings, and a preheated air supply, and by more scientific control of the exit gases. Several of the speakers pointed out that the chief difficulty would be to find materials which would stand the high temperatures attainable under these conditions; and reference was made to siloxicon and other products of the electric furnace as being most likely to meet the special requirements of the case.

We may draw attention to an article published by Mr. F. A. G. Fitzgerald in *Electro-chemical Industry* of November, 1904, which bears upon this discussion; since the author discusses the refractory materials available for lining electric furnaces, in which, it is almost needless to say, the temperature much exceeds that obtainable in any boiler furnace fired with solid fuel. Mr. Fitzgerald shows that there are three types of refractory material available for electric furnace linings. For the lower ranges of temperature he recommends the silicon carbides of a non-crystalline type; for the next higher range he advises the use of crystalline silicon carbide, generally known and sold under its trade name of "carborundum," and for the highest temperatures of all, charcoal. Upon the use of silicon-carbides for furnace construction Mr. Fitzgerald says, "To substitute bricks made of a silico-carbide for fire-brick is not advisable, since the silico-carbides are much better heat conductors than ordinary fire-bricks. Hence if they are used alone, they cause a serious loss of heat, and should not be used, except in those places where a good heat-resisting material is required."

The various methods of making bricks from the silico-carbides are then discussed by Mr. Fitzgerald at some length, and the limiting temperature at which the crystalline variety of this product is useful is stated to be 3,500° C., at which temperature carborundum is separated into its elements, carbon and silicon.

In a letter published in the same issue of *Electro-chemical Industry*, Mr. E. K. Scott gives details of some experiments carried out at Maroker, in Norway, with native magnesite. This material was obtained from mines in Southern India, and the attempt was made to mould bricks of this, and then to convert these into blocks of crystalline magnesia by submission to the heat of an electric arc furnace. These experiments failed, presumably owing to the great shrinkage and contraction which would follow the loss of water and carbonic acid gas by the half-finished bricks. But Mr. Scott goes on to state, that when applied as a wash to ordinary furnace linings of fire-brick, magnesite has been employed with some success. Mr. Fitzgerald, however, criticises this statement, and gives details of some experiments made by himself and Mr. Bennie at Niagara Falls, in which they employed magnesite for a portion of the lining of an electric arc furnace. The temperature of the furnace was well below that required for the production of "carborundum" (namely, 3,900° C.), but at the end of eight hours' heating the magnesite lining, which was 1·6 inches thick, was completely fused. Carborundum and siloxicon would therefore appear to be the most refractory materials at present available for furnace linings, and from time to time we shall publish information as to the results obtained in practical trials with these two compounds.

Artificial Diamonds

THE official programme of special lectures, to be delivered during the meeting of the British Association in South Africa in August, has been published recently; it contains the interesting announcement that Sir William Crookes will discourse on "Diamonds" at Kimberley, the centre of the South African diamond-mining industry. In view of this fact, and the probability that Sir William Crookes will have something to say on the subject of artificial diamonds, the following details of the latest researches* of the distinguished French chemist, Henri Moissan, on this subject, will be read with interest.

* Comptes Rendus. Vol. 140, p. 277.

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These researches and new experiments were based upon the theory that the presence of certain impurities in the molten metal, from which the carbon separates in the crystalline form, will assist the displacement of the carbon; the other elements capable of entering into union with the iron take its place, and in this way larger diamonds may be obtained than in the earlier series of experiments carried out by Moissan in Paris some years ago. Sulphur, phosphorus, and silicon were named as elements likely to act in this way; the presence of these having been ascertained in the famous Cañon Diablo meteorite, which also contained minute fragments of crystalline carbon—or diamonds.

Moissan's experiments with the first-named impurity, sulphur, were carried out as follows:—

Swedish iron was broken into fragments and melted in the presence of carbon obtained from sugar, in an electric furnace; a circuit of 400 amperes at 120 volts being employed. After the iron had taken up as much of the carbon in the form of carbide as it could hold at the temperature attained in the experiment, a small quantity of iron monosulphide was added, and the molten mass was rapidly cooled. This rapid cooling of a mass of highly-heated metal is Moissan's method for obtaining the great pressure required to produce crystallisation of the carbon separating from the metal; since the crust of metal forms outside the molten mass, and necessarily contracts during solidification. The diamonds the French chemist obtained by this method of procedure, with the addition of iron sulphide to the molten mass, were of the same order and size as those obtained in his earlier experiments, and the only difference observed was that the yield, though still small, was distinctly better. In a single ingot of rapidly cooled iron, Moissan states that he found eight or ten minute diamonds, of which half or two-thirds could be separated without the aid of a magnifying glass.

Experiments with iron silicide, added to the molten metal at the moment of cooling, gave similar results. The yield was slightly larger than before, but the diamonds were too small to be of any commercial value. Iron phosphide, on the other hand, gave no diamonds at all.

The manufacture of artificial diamonds in the electric furnace has, therefore, not yet progressed beyond the laboratory stage. It will be interesting to learn whether Sir William Crookes has anything new to communicate, on this aspect of his subject, at Kimberley in August.

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Motor-Car Change-Speed Gears

THE internal combustion engine is efficient only between very narrow limits, and its power varies practically as its speed; hence the use of the engine to drive motor-cars necessitates the employment of change-speed gearing for altering the speed ratio between engine and road wheels.

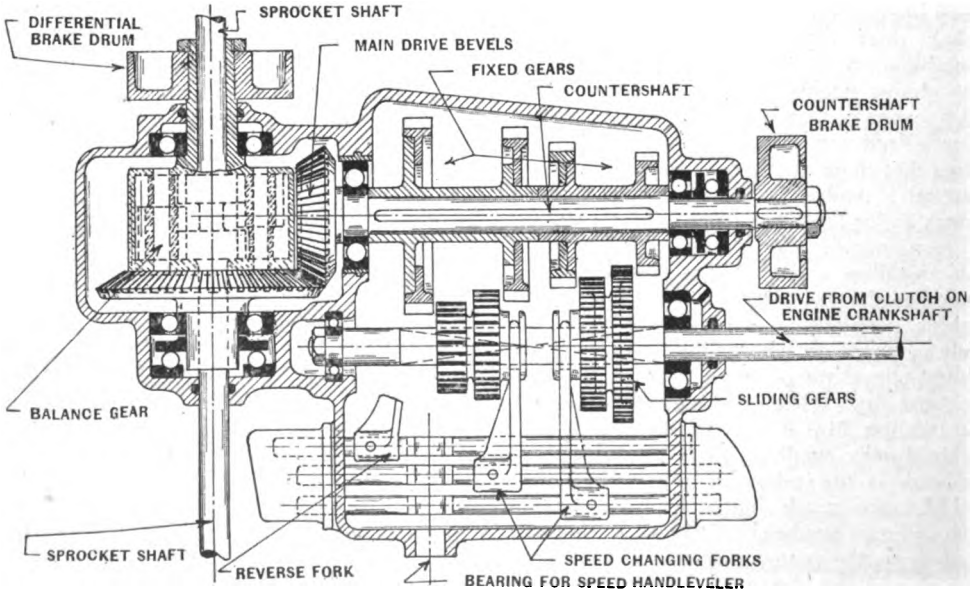

FIG. 1.—SPUR-WHEEL CHANGE-SPEED GEAR FOR MOTOR CARS.

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Many devices have been tried; but the one that is most successful, and is now almost universally adopted, is an arrangement of spur gears on two shafts, arranged so that various pairs of gears may be slid longitudinally into mesh. It is usual now to arrange for four forward speeds and one reverse. The ratios of the forward speeds are about $1 : 2 : 3\frac{1}{4} : 4\frac{1}{4}$; these are found to give a car ample hill-climbing power, while allowing it to maintain the highest possible speed on the level.

The generally accepted arrangement of gearing in use on the latest cars is shown in Fig. 1, although naturally every make has its points of difference. This system appears extremely barbarous and unmechanical, but is evidently the most satisfactory, as the standardisation of machinery always involves the survival of the fittest.

A little "knack" is required to "change" the gears, but a knowledge of what must be done renders it very simple with a well-designed gear. The ideal gear would be one in which the sliding wheel has no momentum; but, as this is naturally impossible, it is desirable to keep the momentum at a minimum.

Changing Gear

SUPPOSE it to be desired to change from a low gear ratio to a higher, as shown at A and C (Fig. 2), the lower pair of gears (the sliding ones) being normally driven by the engine, through a clutch, at 500 revolutions per minute.

The upper pair of gears, which are positively geared to the road wheels, are driven by the momentum of the vehicle, after the sliding gears have been moved out of mesh into position B; the clutch, of course, having been withdrawn preparatory to moving the gears.

It is evident that before the high ratio pair of gears can be meshed, they must have the same peripheral velocity; but a slight change in the momentum of the sliding gears can be allowed to take place by the teeth rubbing together, so that if the mass of the gears is small, they can be engaged when running at slightly different velocities. Now, seeing that the clutch is disengaged, the sliding gears will slow down, by friction; as soon as they have slowed down sufficiently (in the example, to 125 revolutions or thereabouts), they may be intermeshed with the fixed gears. When the friction clutch is re-engaged, it will increase the speeds to those shown at C.

On changing from a higher to a lower gear, the case is reversed. When the gears, which have been running at normal speed (as at C), are brought to the "free" position, the peripheral speed of the small sliding gear is too slow for intermeshing at once with the large fixed gear. The vehicle, and with it the fixed gears, slows down; it is only necessary to keep the free gears spinning at their normal speed, and this is easily done by re-engaging the clutch for an instant. When the fixed gears have slowed down sufficiently (in the example, to 250 revolutions), the gears can be engaged; with practice, this can be done every time without the slightest difficulty.

This arrangement of gearing is exceedingly simple to operate, and only looks difficult and barbarous to those who have had no experience with it.

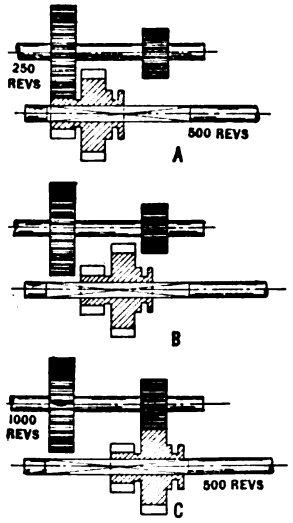

FIG. 2.—TO ILLUSTRATE METHOD OF CHANGING GEAR.

In this example a ratio of 4 to 1 between the gears has been taken, but in practice this is about the ratio between highest and lowest gear, so that one change between such wide limits would never be required. When the changes are between narrower limits, the waits for alteration in gear velocity would be much shorter, in fact, actually, they are only momentary.

Frames for Motor-Cars

THE introduction of the pressed steel frame for motor-cars has enabled designers and manufacturers to more fully comply with requirements, as the frames can now be made of any requisite shape or form almost as cheaply as the old straight flitched wood or

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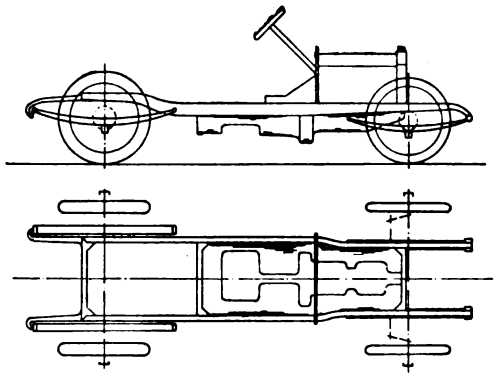

FIG. 3.—PRESSED STEEL FRAME FOR MOTOR CAR.

channel frames could be produced. To give more clearance for the movement of the body on the long springs now customary, it is becoming usual, on the highest class of car, to curve the frame upwards at the back over the rear axle, as shown in Fig. 3.

This also enables the body to be kept rather lower, and is not at all inconvenient, as it merely reduces the depth of the "boot" below the back seat. A frame of this form would, of course, not be suitable for a rear entrance body, but these are now entirely superseded by side entrance types in all but the smaller sizes.

In a few designs another improvement has been effected by casing in the chassis round the motor and discarding the (now old-fashioned) secondary frame. The later types of cars are evidently approaching an ideal for cleanliness: all machinery is completely encased, running in grease or oil baths; the motor is enclosed in a tube with semi-open front and a draught of air induced through it, all parts, at the same time, being rendered readily accessible in case of necessity.

Traction: A Counterweight Line

IN connection with the electric tramway at Balmain, near Sydney, Australia, there is a piece of work meriting especial comment. It consists in the application of the counterweight principle to a single track. Usually the principle is employed on a double track, the descent of a car on one line facilitating the ascent of a car on the other. The extension of the line from Nicholson Street to the Darling Street

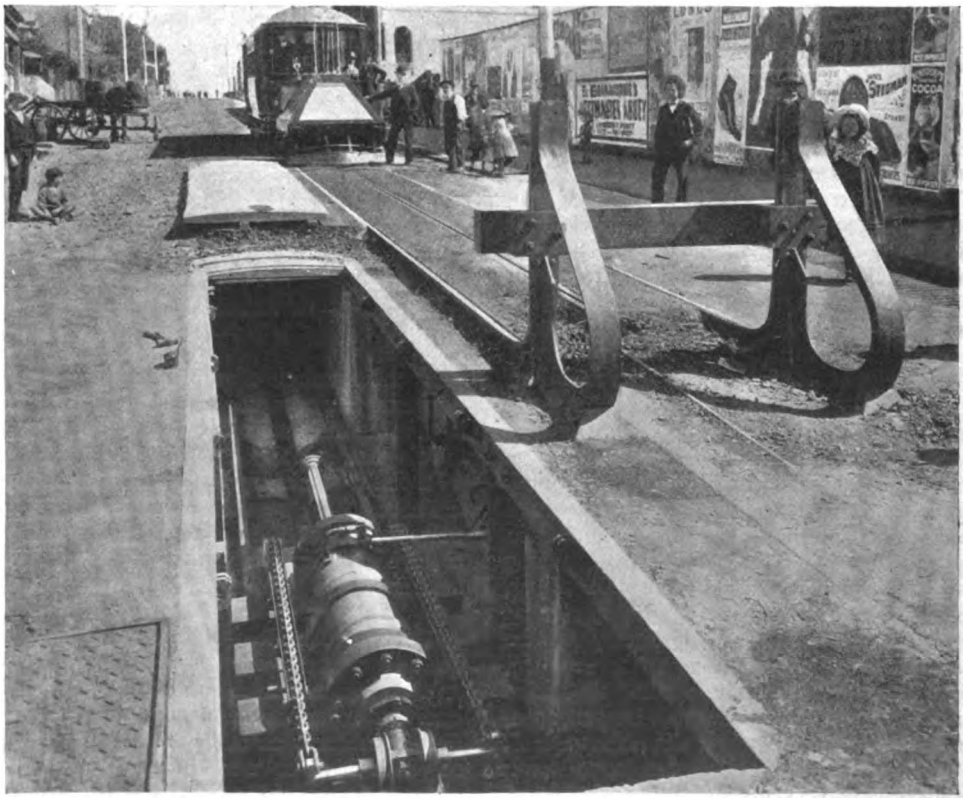

FIG. 4.—COUNTERWEIGHT TRAMWAY, BALMAIN, NEAR SYDNEY, AUSTRALIA.

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Wharf was a matter of much difficulty, owing to the steep descent in the level. Several circuitous routes were considered, but these all involved extensive resumptions of private property; so it was decided to make a direct descent by means of the counterweight cable system, and this was accordingly done. The scheme was devised and worked out by the officers of the State Department of Public Works.

The extension was an extremely short one, being only nine chains in length, but the grade was 1 in 8·48. The permanent way on the street surface is constructed of 89-lb. grooved rails, tied to a centre slot over a tube of concrete similar to cable tramway constructions. Upon this track the cars run, being preceded by a buffer trolley, which has a gripper attached to a steel-wire rope, fixed at one end to a small counterweight trolley, which is weighted to ten tons. This travels on rails laid on a 2-ft. 6-in. gauge in a subway parallel to the tramway track on the surface. The wire rope is led round a 6-ft. horizontal sheave, at a point near where the drop in the level commences, from the cable tube to the subway, at the terminal end of which a hydraulic buffer, with a cylinder 10 in. diameter, 3-ft. 6-in. stroke, is fixed, provided with weights to draw out the buffer-rod after being compressed by the impact from the weighted trolley. The track is bonded, and the overhead wire construction is carried out in the usual manner

An Isomer of Geraniol

By treating oil of neroli with 80 per cent. alcohol, separating the methyl anthranilate, and fractionally distilling a new alcohol of the formula $C_{10}H_{18}O$, an isomer of geraniol has been obtained by Hesse and Zeitschel. The new compound, which has been named "Nerol," and which boils at between 225° and 227° at a pressure of 765 mm., differs from geraniol in not forming a compound with calcium chloride. It has a rose odour.

PATENTEES AND THE PUBLIC.

By JOSIAH ODDY, of the Middle Temple, Barrister-at-law.

1. Where an application for a patent has been made, and a complete specification filed, the Patent Office shall forthwith, in addition to other statutory inquiries, search whether the invention has been wholly or in part claimed or described in any complete specification filed during the fifty years preceding the date of application.
2. Should the search show that the invention has been wholly or in part claimed or described, the applicant shall be informed thereof, and may amend his specification, and the amended specification shall be investigated in like manner as the original specification.
3. If the Patent Office is satisfied with the specification it is accepted.
4. If the Patent Office is not satisfied with the specification, after hearing the patentee's explanations, and unless the Patent Office objection be removed by amending the specification, the Patent Office shall determine whether a reference to any, and if so, what, prior specifications ought to be made in the specification by way of notice to the public.

THE above concise abstract of the new Patent Act which came into operation on January 1st, 1905, will probably convey to the reader the main principles which must, for the future, guide intending patentees and safeguard the public against bogus patents.

Until the year 1902, when the new Act was passed (though its operation has been deferred until now), the Crown gave a patentee practically an unconditional grant, as distinguished from the rigorous examination for novelty enforced by Germany and the United States.

The respective advantages of the British and foreign systems have been much discussed, and might be said to have culminated, so far as this country is concerned, in the appointment of a powerful and representative Board of Trade Committee of Inquiry. The Committee appears to have struck the golden mean between the existing British and foreign systems, and its recommendations are embodied in the paragraphs which preface this article.

How far the new Act will succeed may be said to depend upon the efficiency of the Patent Office. The system is only half as rigorous as that of Germany and the United States, and it may be safely said that in neither of those countries is the Patent Office efficient; the

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staff of examiners in each case is wholly inadequate to understand the patents filed and to search for their novelty. The consequence is that the reports of examiners are being constantly reversed, old inventions are being accepted, and new and valuable inventions as often rejected.

In one case alone, that of Steinmetz's patent for improvements in motor-meters, filed November 21st, 1896, it was not until February 23rd, 1904, that the inventor succeeded in establishing his rights against the improper action of an examiner.

In view of such experience, we are inclined to admire the caution with which the British Legislature has embarked upon the troubled waters of reform. Having given statutory effect to the recommendations of the Board of Trade Committee, they immediately set about preparing the way for working the Act. Competitive examinations were instituted for the appointment of examiners, and the Patent Office started at the beginning of the present year with twenty-four chief examiners, twenty-four deputy examiners, and a hundred and thirty-one assistant examiners. They will have about sixteen thousand complete specifications to deal with in the course of the year, and the number of official working hours is set down in the official report of 1901 at 1,430. This allows about sixteen hours to an examiner for each application. It is doubtful whether this will be adequate. It is certainly a longer time than is allowed examiners in the United States or Germany; but that is no criterion, because what constitutes one invention here would constitute four inventions there. For instance, one patent on the subject of golf balls here was found to include the subject matter of nine United States patents, so that the examiner here in such a case would have to do the same amount of work on one patent as the United States examiner expended upon nine.

Similarly in Germany an English patent for a type-writing machine had to be divided into five German patents. It is evident, therefore, that the present staff, with which the British Patent Office is endeavouring to work the new law, is not over-liberal.

Let us assume that we have an adequate staff of examiners, adequately equipped for their work, how do they proceed? The examiner who has charge of an application first peruses the provisional and complete specifications, from which he should learn how the invention is to be carried into effect. He then reads the claims for the purpose of ascertaining what it is the applicant seeks to hold a monopoly of, as his invention. With this knowledge before him the examiner then makes his search back for a period not exceeding fifty years; after which he reports whether the Comptroller should accept the specification, or whether the specification should be amended, or whether the specification should be endorsed with references to prior specifications.

If the Comptroller has been advised to accept the specification, it is open to public inspection for two months. If no opposition be filed within that period, the patent may be sealed.

If the examiner finds the invention in part claimed or described in an earlier specification, the patentee will receive notice of objection, and must amend accordingly. The same must be exposed for two months' public inspection before being finally sealed.

Should the examiner find the invention wholly anticipated, he will stop his search and report the invention entirely old. The would-be patentee will then be heard by the Comptroller, to determine what reference to prior specifications should be inserted in the applicant's specification before granting a patent.

It will be observed that this limits the Comptroller's power and safeguards the public.

If the applicant should differ from the Comptroller—which is more than likely—as to his invention being wholly anticipated, no harm can be done by allowing the applicant to receive his patent for what it may be worth, provided the public are warned of prior specifications which the Comptroller may consider an anticipation of the applicant's invention.

If satisfactory amendments are not made by the applicant after due notice, the Comptroller, who is acting not only in the interests of inventors, but who is also safeguarding the public, has the power of stating his objections in detail; and Mr. John Cutter, K.C., has expressed the hope that particular parts of a specification will be referred to, following the practice customary when specifications are referred to in particulars of objections in patent actions.

Various eminent writers have manifested much distress at the possibility of such a course. They are afraid the poor patentee will have his specification so littered with *references* to prior specifications that he will be in the position of a guilty publican whose license has been endorsed. And what matter, if, like an offending publican, it means that he is unfit to have a license from the Crown? He is trying to palm off a worthless thing and get the imprimatur of the Patent Office as a mark of its value.

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BALLISTICS OF MODERN RIFLES.

PART III.—INTERNAL BALLISTICS.

Continued from No. 16, p. 315.

By R. H. HOUSMAN, B.Sc., M.I.E.E.

BY a series of successive approximations the movement of the bullet, and therefore the increase of volume occupied by the gases, can be calculated; the diminution of the surface due to combustion being taken into account at each step. The result of this calculation is shown in Fig. 6, curves A and A', which show the variations of pressure with time and travel

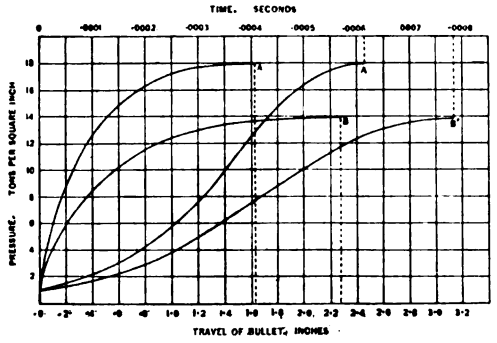

FIG. 6.—CURVES SHOWING VARIATION OF PRESSURE WITH TIME AND TRAVEL OF BULLET.

A, *pressure curve for strand cordite.* A' (*lower curve marked* A), *time curve for strand cordite.* B, *pressure curve for* 0·022 *in. flat strip cordite.* B', *time curve for* 0·022 *in. flat strip cordite.*

of the bullet. It appears that the bullet moves about $1\frac{5}{8}$ in. before the maximum pressure is attained, the corresponding time being a little over 0·006 second; the calculated pressure is just under 18 tons.

The results of a corresponding calculation for a similar charge of sheet cordite 0·022 in. thick is shown in curves B and B' (Fig. 6), the surface in this case being taken constant at 7 square inches. The pressure is reduced to about 14 tons in this case, which agrees very well with the observed result of 14·4 tons with flat strip 0·185 in. × 0·022 in., in which case the initial surface is about $7\frac{1}{2}$ square inches, and the final about 6 square inches, which accounts for the slightly higher pressure. The time of reaching maximum pressure is nearly 0·0008 second, and the travel of the bullet a little over $2\frac{1}{4}$ inches.

These calculations can only be considered approximate, but they are sufficiently in agreement with experiment to justify the assumptions which have been made with regard to the proportionality of the rate of burning of cordite to the pressure. A further assumption made in these calculations is that a constant proportion of the work done is absorbed by friction, this proportion being taken as 25 per cent., which represents about an average of the result of a large number of experiments in which the muzzle energies and the indicated energies of various charges were compared. The friction seems to be higher with cordite than with some other powders for which the proportion of the total work absorbed by friction is 20 per cent. or less.

Experiments with charges giving pressures from 13 to 28 tons per square inch show that the percentage lost in friction is nearly constant, the increase of friction with pressure being very clearly indicated. In consequence of the assumption that the acceleration of the bullet is always 0·75 of that which would be caused by the pressure acting without friction, the variations of pressure due to the difference

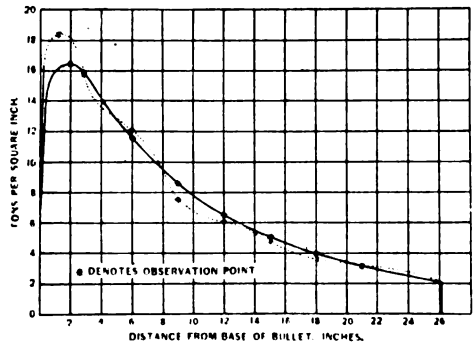

FIG. 7.—*Full line curve represents result of experiment in which waves were not produced. Dotted line curve shows the result when waves were fully developed.*

in the "lead" are ignored; but a calculation made on the supposition that the bullet moves freely for 0·2 of an inch, and then encounters a resistance equivalent to about 5 tons per square inch (as in the 0·303 "short lead") whilst the bullet is entering the rifling, gives very similar results.

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One of the greatest difficulties encountered in these investigations has been due to the existence of pressure waves, in consequence of which a given cartridge may one day give 16 tons, and another day 19. The existence of these waves is much more evident when using small crushers and light pistons than when larger crushers and heavier pistons having a greater time lag are used. It is supposed by some that these variations are due to the untrustworthiness of the crusher gauge, and therefore that small are less trustworthy than large crushers, because the former show greater variations. We consider, on the contrary, that the small crushers indicate more truly the maximum pressure in rifle barrels than large ones, since they will indicate the existence of a wave whose period is only about 1/10,000 of a second. These waves must be considered important in determining the stress in the barrel, since the time of radial vibration of the latter is less than 1/100,000 of a second.

Fig. 7 shows two curves taken from the same lot of cartridges on different days. One of these shows the existence of waves which are either not present in the other case, or, if present, happen to have their nodes near the positions of the crusher pistons. It often happens that a series of similar charges with different thicknesses of cordite will all, on one day, show a series of waves having their maxima at nearly the same points in the barrel and all show smooth curves on another day. On this account, pressures in big guns are generally taken by comparison with a standard charge, and a "correction for the day" applied, to give what is considered to be the normal pressures of the charges under test; this is an attempt to eliminate the effects of the waves, which vary from day to day.

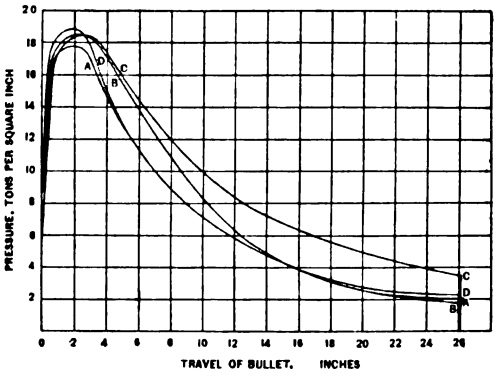

FIG. 8.—PRESSURE CURVES FOR VARIOUS CHARGES IN 0·303 RIFLE.
(*For data, see Table IV.*)

Fig. 8 shows the pressure curves of various charges in a 0·303 rifle, and indicates the possibility of increasing the power of the weapon without materially raising the pressure. The figures given in Table IV. show velocities taken in the pressure gun simultaneously with the pressures, which are about 70 ft./sec. lower than those given in a rifle having a "short lead." A very complete series of experiments has shown that a velocity of 2,300 feet per second may be obtained with flat strip cordite M.D., without exceeding the pressure of the Service cartridge. The special advantage of cordite M.D. is the reduction of the heating and erosion of the barrel, which is very marked when any attempt is made to increase the charge of Mark I. cordite in order to get improved ballistics. By increasing the length of the case and then adding 20 per cent. to its capacity, velocities up to 2,500 ft./sec. may be obtained for about 19 tons pressure. With a strong breech action, such as in the Mauser or Mannlicher, pressures of 24 tons per square inch are quite safe, and would give velocities up to 2,700 ft./sec. with the long case. The advantages of such a velocity as this will be treated of under the head of "external ballistics."

In using either flat strip or flake powder in the place of round strands, it is necessary to keep the thickness within very narrow limits, since even 1/1,000 inch variation has a distinct effect on the ballistics obtained. The proper thickness may be calculated from the velocity desired, the weight and diameter of the bullet, and the mechanical efficiency.

The method of calculation is as follows:—The value of the product of pressure and net volume produced by a grain of cordite is

TABLE IV.—DATA REFERRING TO CURVES IN FIG. 8.

	Velocity.	Muzzle Energy.	Indicated Energy.	Mechanical Efficiency.	Pressure.
	ft./sec.	ft.-lbs.	ft.-lbs.	Per cent.	tons sq. in.
A.—30 grains 0·033 strand	2,043	1,988	2,627	75·7	17·9
B.—35 grains 0·1 × 0·015 cordite M.D. . . .	2,257	2,425	2,853	85·2	18·6
C.—45 grains 0·1 × 0·019 cordite M.D.(long case)	2,392	2,723	3,400	80·2	18·3
D.—36 grains German flake powder	2,100	2,100	2,686	78·2	18·9

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0·276 inch-ton; and since there are 394 grains to the cubic inch, the value of P.V. given by each cubic inch of cordite is 108·6 inch-tons.

At 1 ton per square inch the combustion of 1 cubic inch of cordite burning over a face 1 inch square will last 108·6/95 = 1·144 sec., since 95 cubic inches of gas are given off per square inch per second; so that the product of pressure and time required to burn 1 inch thickness is 1·144 ton-secs. This would give, to a piston exposed to the pressure, a momentum per square inch of 1·144 × 2240 × 32·2 = 82,500, so that a momentum per square inch = 1000 will burn 1/82·5 inch thickness of cordite on one face, or 2/82·5 on two faces, or about 0·0243 inch.

It is usual in practice to deal with the weight of projectile per circular inch, or $\frac{W}{d^2}$ rather than per square inch, or $\frac{W}{\frac{11}{14}d^2}$; so that the most convenient quantity to use is what may be called the "sectional momentum," or product of velocity into sectional density, *viz.*, $V \times \frac{W}{d^2}$. The thickness of cordite burnt is proportional to this sectional momentum. Since 0·0243 inch diameter is burnt by a momentum per sq. in. of 1,000, therefore 0·0309 inch will be burnt for a sectional momentum of 1,000. The sectional momentum of the 0·303 bullet at the muzzle is $\frac{2{,}050 \times 215}{7{,}000 \times (0{\cdot}308)^2} = 664$. This is less than that given to the bullet by the amount which has been lost in friction, so that the sectional momentum given to the bullet is $\frac{664}{0{\cdot}75} = 886$. The thickness of the cordite burnt at the muzzle is 0·886 × 0·0309 = 0·0274 inch, leaving 0·0056 inch unburnt.

For flat strip cordite the combustion must be complete long before the bullet reaches the muzzle, which is allowed for by taking the velocity at 10 inches or 12 inches from the breech, which is 75 to 80 per cent. of the muzzle velocity. This gives a thickness of 0·0274 × 0·8 = 0·022 inch.

As an example of the extension of this method of calculation to big guns, take a 12-inch gun with a muzzle velocity of 2,360 ft./sec., and a projectile weighing 850 lbs. The mechanical efficiency in this case is probably at least 0·95, and the sectional density is $\frac{850}{144} = 5{\cdot}9$. The sectional momentum given to the shot is $\frac{5{\cdot}9 \times 2{,}360}{0{\cdot}95} = 14{,}660$.

The thickness of cordite burnt up to the muzzle is 14,660 × 0·0309 = 0·453 inch, the thickness of the strands being 0·46 inch. The combustion is just completed as the shot leaves the muzzle, which is what is generally considered the correct practice with strand cordite.

(To be continued.)

TANTALUM AND CARBON FILAMENT LAMPS COMPARED.

Messrs. A. E. Kennelly and S. E. Whiting contributed an interesting article on the above subject to a recent number of the *Electrical World* of New York. An ordinary carbon filament lamp was found to have a resistance of 600 ohms when cold. As the voltage across the filament was increased, the resistance fell to a minimum of 288·2 ohms at 75 volts, remained stationary up to about 90 volts, and then slowly increased to 293 ohms at 140 volts. The tantalum filament had a resistance of 55 ohms when cold, and the resistance increased quickly at first, and then more slowly as the terminal voltage was increased, reaching 316·8 ohms at 143·3 volts. It was found that, under working conditions, an increase of 5 per cent. in the voltage produced an increase in the current equal to 3·75 per cent. The power absorbed by the tantalum filament is greater at low voltages, and less at high voltages (such as those used under working conditions), than that absorbed by the carbon filament. At 110 volts the tantalum lamp consumed 2·2 watts per candle; the carbon lamp consumed 4·3 watts per candle at 120 volts, its normal voltage. The normal efficiency of the tantalum lamp was, therefore, nearly twice as great as that of the carbon filament lamp.

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THE APPLICATION OF ELECTRICITY TO MINING.

By JAMES TONGE.

IT will be readily conceded, we imagine, that the mining of the useful minerals such as coal, iron, lead, zinc, tin, copper, gold, etc., forms one of the most important industries of this and many other countries; and one moreover to which the best thought has been given and the highest skill applied. It is not surprising, therefore, that mining engineers have taken advantage of the recent rapid advances in the science of electricity, and are seeking to apply it as a motive power to many departments above and below ground, in both coal and metalliferous mining.

Electricity, in all but one respect, is eminently adapted to use in mines. It is serviceable, effective, convenient and economical in use, and lends itself admirably to winding, hauling, drilling, cutting, ventilating, lighting and pumping. The one exception is its danger, especially in fiery coal mines; but this drawback is being gradually overcome, and its entire elimination may be looked for at no very distant date.

In Germany, Belgium and France, many of the principal mines, both coal and metal, are equipped electrically throughout; in the United States it is a common power; in England and many of her colonies it is in use for all the purposes named except winding, from the cutting of coal on the one hand to the dressing of ores on the other. There are many advantages to be derived from the use of electricity. The ease and regularity of its production, its elasticity and adaptability to various operations, and finally its economical generation and application, are no mean features in its favour in an industry where the conditions of working are both difficult and dangerous.

We propose, in this article, to refer to the most modern arrangements for its generation and distribution, and the various purposes to which it can be applied in mines.

Central Electric Installation.

Generally a central generating plant is set up, and from here the power is distributed to different shafts and workshops, in the manner most conducive to economical working; the flexibility of the electric system, which is almost independent of distance, allows this to a degree seldom attained with steam or compressed-air transmission. The station

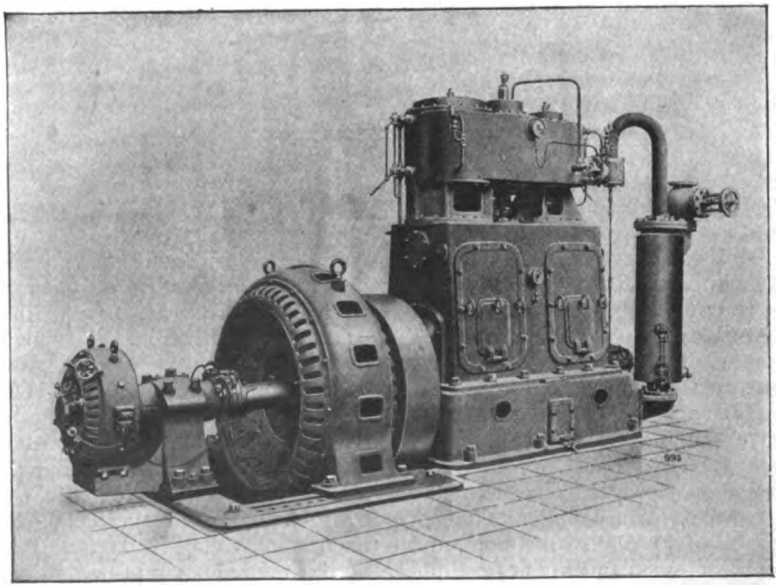

FIG. 1.—ENCLOSED COMPOUND ENGINE AND MULTIPOLAR ALTERNATING DYNAMO (Messrs. Scott & Mountain).

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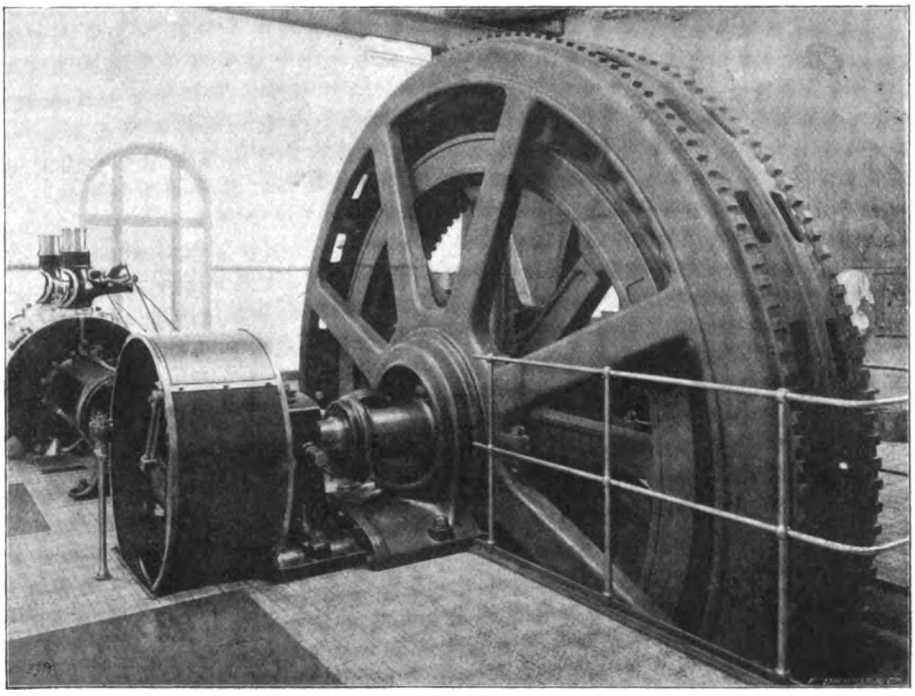

FIG. 2.—600-H.P. THREE-PHASE GENERATOR, OF THE INTERNATIONAL ELECTRICAL ENGINEERING COMPANY.

is placed near to the boilers, the generators being driven, as a rule, by high-speed expansion engines (with automatic governors, forced lubrication, and cut-offs) or turbines, and the whole of the plant is fitted with the most modern appliances, both for ensuring safety and trustworthiness in working and for economising steam, and consequently coal. There are different designs, for each of which some advantages might be named, such as: (*a*) Slow-running engine having armature of dynamo coupled direct on to crankshaft. (*b*) Slow-running engine coupled by ropes or belt to dynamo. (*c*) Quick-running vertical engine having armature of dynamo coupled on crankshaft (Figs. 1 and 2). (*d*) Extra quick-running steam turbine having armature directly coupled. These engines are arranged so that one or more can be running at one time, and as there are often some parts of the day when more current is called for than at others, the spare engines are set to work accordingly.

DISTRIBUTION.

The systems for use in collieries may be divided under two main heads, *viz.*:—

1. Polyphase alternating-current system.
2. Direct-current system.

For coal-mining work there can be no doubt that polyphase-current machinery is superior to direct-current machinery. This superiority is chiefly due to the polyphase induction motor, which has neither brushes, commutator nor slip rings, so that there is not

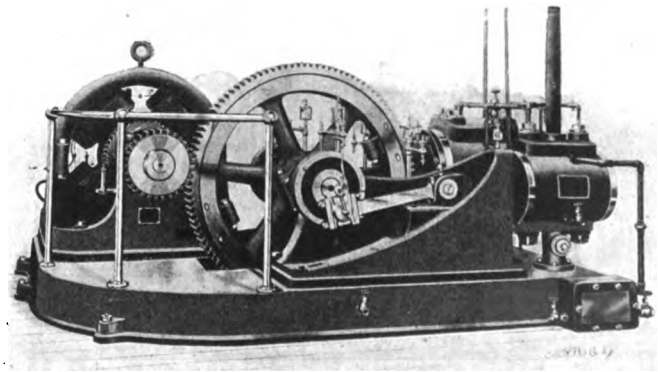

FIG. 3.—INGERSOLL-SERGEANT ELECTRICALLY-DRIVEN AIR COMPRESSOR.

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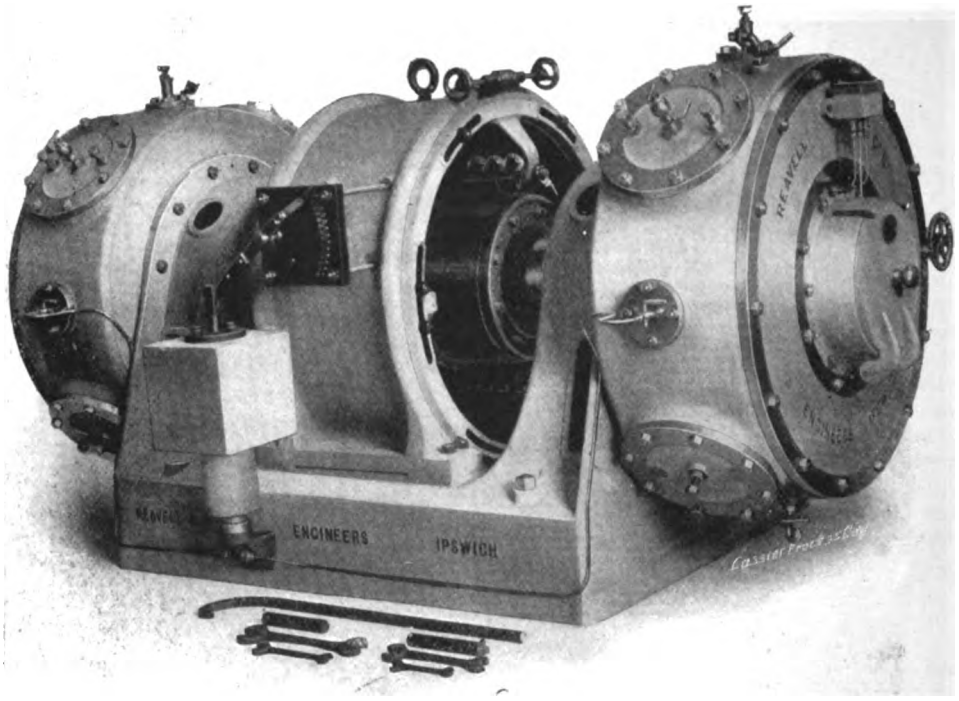

FIG. 4.—REAVELL ELECTRICALLY-DRIVEN AIR COMPRESSOR.

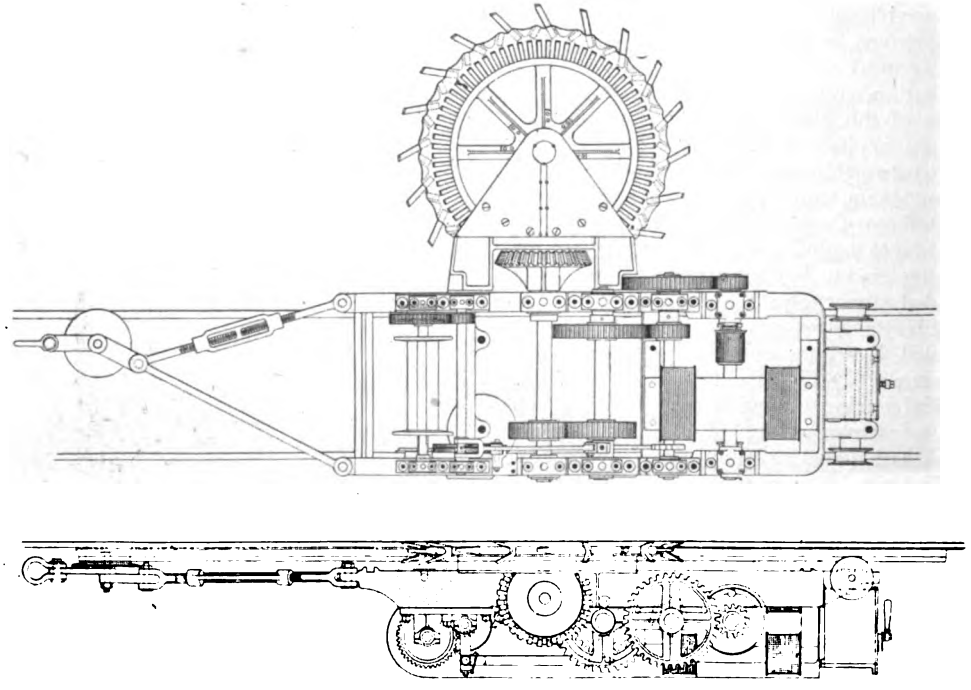

FIG. 5.—PLAN AND ELEVATION OF ELECTRIC LONGWALL COAL CUTTER.

(Reproduced by the kind permission of the Council of the Institution of Mining Engineers.)

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only entire freedom from sparks, but the absence of these sensitive parts is a great gain where motors are often entrusted to the care of unskilled men or exposed to dust, dirt and damp. Some exceedingly serviceable motors of this type are in use. The Westinghouse type "C.B." motor has a strong starting torque, which enables it to start easily under loads, and it may even be pulled up dead by extreme overload without injury—a feature impossible in other types of motors, but of great advantage in mining under certain conditions.

For coal-cutters, it has hitherto been found well-nigh impossible to construct polyphase motors of sufficient power for the exceedingly difficult work of cutting, and yet small enough to be taken into a thin seam. But the great stress laid on the necessity for such motors, by the Departmental Committee on Electricity in Mines, has induced many firms to attempt to devise a suitable three-phase machine. The Diamond Coal Cutter Company have overcome the difficulty by using two motors arranged end to end, so as to reduce both height and width. The motors have their rotors connected through slip rings to the primary circuit, the stationary coils being connected through a rheostat, thus obviating the necessity of carrying the heavy current through slip rings. It is always difficult, in the case of a coal-cutter motor, to devise a suitable arrangement for short-circuiting the slip-rings, but without this the extra resistance in the circuit would seriously reduce the efficiency of the motor. The arrangement described obviates this difficulty. In former patterns of polyphase machines, the motors were of the short-circuited rotor type, started either through an auto-transformer or with a mechanical slip in the gearing; but neither of these methods could be considered satisfactory.

For transmission over long or short distances, polyphase machinery is equally applicable, the pressure being varied accordingly. For long distances, high voltages are advisable, pressure if necessary being reduced by transformers placed at suitable points.

For special purposes, such as driving electric locomotives and pit-bottom haulage engines, or for use in small or non-fiery mines, direct-current may be employed. In this case the generating station would contain two or more dynamos, connected up on either the "two-wire" or "three-wire" system. The British Westinghouse Company have introduced a double-current generator capable of furnishing both alternating and direct current simultaneously in required proportions, and this has proved of great service at some mines where both kinds of current are used, being considered preferable to the adoption of both direct and alternating current generators, the one to supply power for locomotives and hauling engines, the other to be used for the cutters, pumps and lights.

Cables.

It will readily be seen that the question of the best form of cable for use in mines is a serious one. In their report the Electricity in Mines Committee pointed out the great difficulty of guarding against all cable risks. The conditions met with in mining are generally more unfavourable than those experienced elsewhere. The atmosphere is generally warm, sometimes damp, and frequently the presence of acidulated water adds to the difficulties of maintaining an effective insulation. Even in shafts and roadways there is great liability to abrasion from external causes, owing to falling bodies in shaft, falls of ground below, lifting floors, and derailed tubs. On the working faces and the roads adjacent thereto the risks are still further increased; restricted space, the constant need of alteration, greater liability to damage from falls, all tend towards greater wear and tear and necessitate greater care than is the case with main road cables.

In shafts, the cables are often suspended from the surface, being hung from special insulating clamps. It is also necessary to clamp them at intervals down the shaft unless they are specially strong. Very often a special form of cable is adopted, which is easily capable of bearing its own weight from top to bottom. This cable is specially armoured with galvanised iron wire. For special precaution it is sometimes encased in iron pipes of small diameter. Armoured cable is also most serviceable underground, forming a good protection against the bad effects of a short circuit and consequent burning of the wires.

Electrically-driven Air Compressors.

Notwithstanding the excellent results obtained by electricity, there are certain purposes for which compressed air seems the ideal power. In some mines it may be the only motive power which can with absolute safety be adopted at the face, and failing the introduction of an efficient electric percussive drill, it is impossible to dispense with pneumatic drills in metalliferous mines, for it is in the latter that by far the greatest number

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of power drills are employed. The great drawback to compressed air is its low efficiency, especially when used at great distances from the compressor, unless large air-pipes are used. On the other hand, it is safer than electricity, and can be applied easily to many different purposes. But in many extensive metalliferous mines, and in some fiery coal mines, a combination of the two means of transmission seems the ideal one, *i.e.*, to carry electric current as far into the mine as is convenient or safe, and at this point to drive a plant for supplying compressed air to the drills, cutters and pumps. In this way great loss of power due to distance is avoided, while at the same time the percussive form of drill, so efficient in rock boring, is retained.

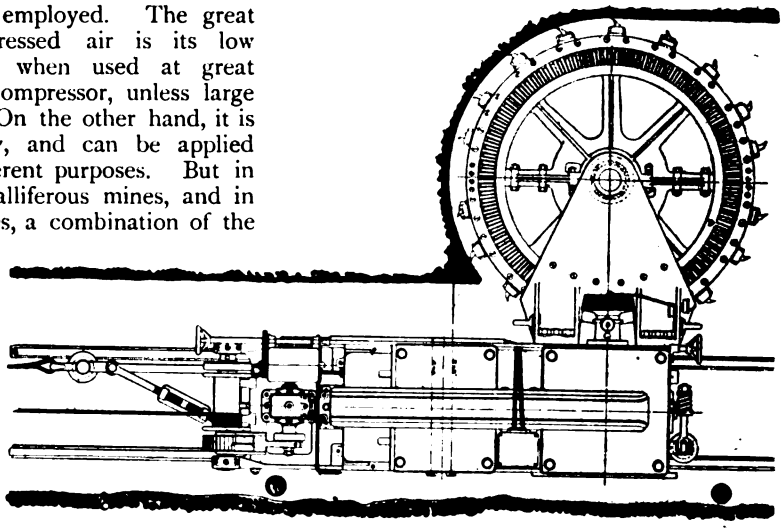

FIG. 6.—PLAN OF LOW TYPE ELECTRIC COAL CUTTER.

Compressors require a practically constant torque or turning moment in the motor, and the speed variation required is usually small. If direct-current distribution is adopted, it is generally best to have compound motors and to vary the speed if necessary by means of a rheostat in the field current. An excellent air compressor, suitable for this work, is shown in Fig. 3. This is made by the Ingersoll-Sergeant Drill Company, London. It is a compound engine with piston inlet cylinders, made to give from 81 to 1205 cubic feet of free air per minute. Compressor and motor being mounted on same base, accurate alignment is obtained. The machine is entirely automatically controlled for the varying air requirements, a special air-pressure controlled self-starting device being used.

Another compressor made by Messrs. Reavell and Co., Ipswich, is shown in Fig. 4. This is a direct-coupled double-ended compressor. Gears are dispensed with, and a highly efficient and compact machine is thus obtained, very suitable for underground use.

ELECTRIC COAL CUTTERS AND ROCK DRILLS.

It may be said that it is only in recent years that mechanical coal cutters have taken the place of hand holing to any appreciable extent, and in this country we are far behind the United States in this respect. In the latter country about 28 per cent. of the total coal production is machine mined; in the British Isles, less than 2 per cent. of the total output is produced by machines. As more than half of the coal cutters are operated by compressed air, it will be seen that the electrical coal cutter is not yet by any means well established. Outside this country it is practically unknown.

Coal cutters are of various forms, according to the purposes for which they are required. For the driving of roads or headings, pick or puncher machines are employed, but these are generally operated by compressed air. For this work also, chain heading, shearing, and channelling machines are in use. On longwall faces rotary disc machines are most common, but since the advantages of electric power for coal cutting have been recognised, revolving bar and revolving chain cutters have been used with considerable success.

We propose to describe shortly the mode of working of each of these types of machines.

In a rotary disc machine, the knives or cutters are arranged on the periphery of the wheel, connected by gearing to armature shaft as shown in Fig. 5; the coal is cut as the wheel revolves, and the machine moves slowly along the face. Longwall machines are always self-propelling, being provided with a small drum and rope, the latter being passed round a post some distance along the face, and coiling on the drum when the machine is at work, at a speed regulated by the speed of the cutting wheel. In most cases the wheel clears itself and is arranged to cut quite level with the floor; but it may be raised to cut midway in the seam, or even on the top of the coal. The machines run either

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on rails, sledges, or on the hard floor of the mine, being guided in their journey by ropes or posts. Electric cutters weigh up to 3,500 lbs., are worked at voltages of 500, 250, or 220, with motors up to 25 h.p. Height, about 20 inches, but less in thin seams; length, 6 to 8 feet; width, 36 to 38 inches. Depth of holing, 3 feet to 6 feet 6 inches, or 7 feet; height of holing, 4 to 6 inches.

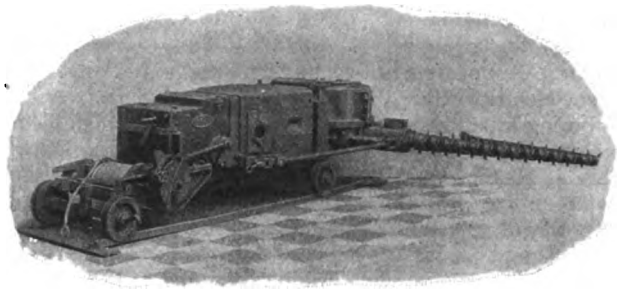

FIG. 7.—"PICKWICK" REVOLVING BAR CUTTER.

Fig. 6 shows an electric long-wall cutter made by Messrs. Scott and Mountain. The machine, with its enclosed motor, is specially designed to resist firedamp and mechanical damage. The overall dimensions of the machine are as follows:—Length over frame, 7 feet 6 inches; width, 3 feet 3 inches; height from rail, 1 foot 2 inches. Total height from floor to top of machine, with rails, 1 foot 10 inches; with skids, 1 foot 8 inches. The machines are arranged to undercut 3 feet 6 inches, 4 feet 6 inches, or 5 feet 6 inches. The frame is made in one piece, being a solid steel casting, and is specially designed to present as smooth a surface as possible. All the working parts are totally enclosed, the motor and gear with cast steel covers and the remainder with sheet steel plates readily removable. The motor for standard machines is of 25 nominal horse-power, capable of developing 40-brake horse-power for short periods, and of giving the full-rated horse-power continuously without undue heating or sparking. The brushes are arranged so that no change in position is required, and carbon block brushes are used in a special radial type of brush-holder. The construction of the armature is such that the windings cannot be displaced or injured by vibration, which is a most important point.

A revolving bar may be substituted for a circular disc (Fig. 7). This bar, standing out at right angles to the machine, has cutters upon it, and these cut the coal as the bar revolves, the clearing being accomplished by a slight backwards-and-forwards movement of the bar. It is very properly claimed that by reason of its higher speed this is the most suitable form for driving by electricity, gearing for only a single reduction in speed being necessary. It is probably best in ordinary circumstances to drive these machines by direct current; but if the adoption of alternating current is determined upon, a low periodicity, not exceeding thirty cycles per second, is preferred. The limitations in respect of diameter, speed of rotation, and complete enclosure of motors, are incompatible with the best design in alternating current motors for higher periodicities. For large bar machines no difficulty is met with if the periodicity does not exceed thirty cycles per second, but for the smaller sizes the use of alternating current is almost impracticable; and in this case, if the supply is alternating, it is necessary to interpose rotary converters, or motor generators to transform to direct current.

For heading, channelling and shearing machines, polyphase current is particularly suitable, as there is always ample space, and machine and motor need not be restricted in size. Heading and shearing machines are chiefly used in the driving of roads, where it is not necessary that they shall move along the face of the workings as they are cutting, the former being used for under-cutting, and the latter for cutting the side of the roadway. The heading machine makes its cut straight to the front. A good example is the Jeffrey electric header (Fig. 8). Shearing and slotting machines for cutting the sides of roadways are now often used. This work may be done by a percussive drill or a channelling machine, but the action of a

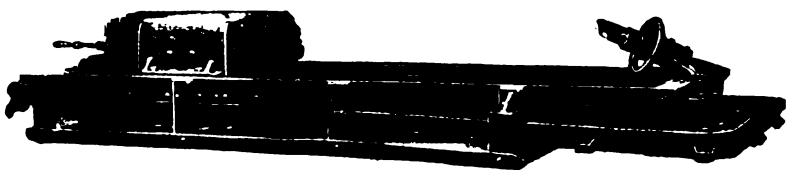

FIG. 8.—JEFFREY ELECTRIC HEADER.

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shearing machine is quite different from the action of either of these.

So far it cannot be said that there is a really efficient electric drill. For the hard work of rock-boring a percussive action is preferable, but electricity does not lend itself so easily to this as to the rotary form of movement, and this probably accounts for the lack both of a powerful rotary drill, on the one hand, or an efficient percussive one, on the other. For this reason, where much drilling has to be done, and electric power is already available, it is found advantageous to have a small electrically-driven air-compressor, as described already, at a suitable point in the workings, and of sufficient capacity to drive three or four percussive pneumatic drills. In the September number of TECHNICS an interesting drill is described, made by the Denver Engineering Company, in which air, *compressed within the drill itself*, actuates a small piston, which in its turn strikes the drill. For many reasons this is an excellent idea, and only one drawback is to be feared, *viz.*: that the addition of the motor will increase the weight of a machine which must already be quite heavy enough. But even this drawback is far less serious than many inseparable from the use of electric rotary drills; it is a common occurrence when using the latter to have armatures fused and other serious breakdowns, caused by a sudden increase in the resistance due to the drill entering exceptionally hard bands of ironstone or other hard strata.

A PERTINACIOUS CURRENT.

ON Friday, March 25th, Sir Oliver Lodge delivered an interesting lecture bearing the above title at the Royal Institution. A "pertinacious" current may be defined as a continuous and unidirectional current at a very high voltage. Such a current can, of course, be produced by a sufficient number of cells (secondary or primary); but these are expensive, and troublesome to keep in order. A continuous current dynamo of sufficiently high voltage can scarcely be constructed, on account of the difficulty of insulating the commutator segments. The current in the secondary of an induction coil is unidirectional but intermittent; if means could be devised to render such a current continuous, we should obtain a "pertinacious" current. If we wish to collect electricity in a battery of Leyden jars connected across the secondary terminals of an induction coil, an electrical non-return valve is needed to prevent the electricity from flowing back through the secondary of the coil during the intervals between the electromotive impulses. Sir Oliver Lodge has found that a vacuum tube of special construction can act as a non-return valve of the kind required. The electrons shot off from the kathode of a vacuum tube clear the "Crookes dark space" of everything but themselves; consequently they may prevent the positive ions derived from the anode from reaching the kathode. As a consequence, it often happens that a vacuum tube of unsymmetrical form has different conductivities according to the direction of the discharge through it. If a V-shaped vacuum tube has a kathode at the bottom facing up one of the legs, while the anode is at the top of the other leg, then the electrons emitted by the kathode will not interfere with the positive ions from the anode, and the tube will conduct readily; if the direction of the current is reversed, the electrode at the top becoming the kathode, then the electrons from this will sweep the leg in which it is situated clear, and the tube will cease to conduct. Hence such a tube can act as an electrical non-return valve, allowing a current to pass in only one direction; if such a tube is suitably connected in series with a battery of Leyden jars across the terminals of an induction coil, a continuous high-pressure current can be obtained from the jars. In an ordinary vacuum tube, however, the conductivity steadily diminishes with use; the gas in the tube appears to be destroyed by the electrons. It is therefore preferable to use a vacuum tube containing vapour (such as that of mercury) which can be renewed when required. Sir Oliver Lodge uses a cylindrical tube placed in a vertical position; at the top of this is an iron electrode, while mercury in the lower end of the tube serves as the other electrode. The outside of the tube is wrapped round with tinfoil as high up as the surface of the mercury; this tinfoil is connected to the upper electrode by a wire. When the mercury forms the kathode, the electrons emitted by this are deflected toward the sides of the tube, and thus offer no opposition to the positive ions; when, however, the upper (iron) electrode becomes the kathode, the electrons from it stop the passage of the current.

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CONCRETE.

By BRYSSON CUNNINGHAM, B.E., Assoc.M.Inst.C.E.

CONCRETE is the name applied to an artificial combination of various mineral substances which, under chemical action, become incorporated into a solid mass. Such is the common, and all but universal, signification of the word. There are, however, one or two compositions of comparatively trifling importance which receive the same appellation, though differing fundamentally from true concrete, their solidification being quite independent of chemical influence. These compositions only call for passing mention; they are: *tar concrete*, made of broken stones (Macadam) and tar; *iron concrete*, composed of iron turnings, asphalte, bitumen and pitch; and *lead concrete*, consisting of broken bricks set in molten lead. The last two varieties, with rare exceptions, are only used in connection with military engineering, such as for fortifications and the like; and all three lie outside the scope of the present paper.

Reverting to the first enunciated and most important (as it is by far the most prevalent) conception of concrete, we may particularise its composition by stating that it consists essentially of two groups or classes of ingredients. The first, termed the *aggregate*, is a heterogeneous mass, in itself inactive, of mineral material such as shingle, broken stone, broken brick, gravel and sand. These are the substances most commonly in evidence, but other ingredients are also occasionally employed, such as slag from iron furnaces. Burnt clay, in any form, and earthenware, make admirable material for incorporation.

The second class constitutes the active agency which produces adhesion and solidification. It is termed the *matrix*, and consists of hydraulic lime or cement, combined with water.

The foregoing method of classification is simple and convenient, and being theoretically sound, it is generally adopted. It may, however, be modified with advantage. For the present it suffices, but when we come to discuss the proportioning of the various ingredients, it will be desirable to rearrange the groups more in accordance with practical purposes.

Before entering upon a detailed consideration of the preparation and uses of concrete, it seems fitting to allude to the fact that concrete is by no means a purely modern invention. On the contrary, it is of a very respectable and even venerable antiquity. It would be difficult to assign an exact date to its origin, but it certainly was in use in the time of the Romans and Carthaginians, as is evidenced by the remains of many of their harbours and other maritime works upon the coasts of Italy and Northern Africa. Yet, in spite of its antiquity, it is only of late years—within the last generation, in fact—that it has acquired the peculiar and pre-eminent position which it now possesses in structural work. Associated with steel, it may, without fear of contradiction, be said to be the most popular and useful building material of the present day. Not only is it used for a vastly preponderating proportion of maritime undertakings—in massive breakwaters, dock and harbour walls and quays—but a wide field of usefulness is found for it in the construction of bridges, arches, dams, culverts, viaducts, roads, sewers, warehouses, and buildings of every description. Private residences are built of it, in some cases almost entirely. A well-known engineer relates how, on one occasion, he came across an Irish farmer, who was so captivated with the marvellous adaptability of concrete that he practically rebuilt his farmhouse, the barns and stables, the pigsty and dog-kennel, with the material, and then expressed regret at being unable to make it up into five-barred gates. That was twenty years ago. Probably by this time the farmer has been able to make his gates. With the agency of ferro-concrete the project is quite feasible, and by no means so ludicrous as it would appear. Much more slender things than farm gates are made of ferro-concrete—skylight bars and louvre ventilators, for instance—while floor joists and beams, columns, bearing and sheeting piles, are but a few of its many and varied uses.

Earlier concretes were manufactured with lime, and not with cement, as is almost universally the practice at present. Portland cement, the best and strongest of modern cements, was of course unknown, being only invented in 1824. Other and natural cements may have been at the disposal of the ancients,

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but this is doubtful. Hydraulic lime was the main, if not the sole matrix employed. The inferior strength and setting qualities of this material may possibly account for the indifferent popularity of concrete during the Middle Ages. Yet it is a significant fact that French and Italian engineers of the present day favour the use of lime for concrete—no doubt on account of the exceptionally excellent qualities of the limestones found along the coasts of the Mediterranean. Another reason for the comparatively restricted use of concrete in mediæval times is possibly to be found in the higher value which was then attached to æsthetic over purely utilitarian construction, and the enormous amount of time and labour devoted to artistic production. A Gothic cathedral would lose much of its impressive grandeur if modelled, however skilfully, in concrete. Nothing at the present day looks more pitifully meretricious and tawdry than elaborate and pretentious ornamentation executed in cement-faced concrete, professedly in imitation of masonry dressings; and scarcely anything could be in worse taste. Concrete is essentially a material for strength, for durability, and for economy; in artistic qualities it is much the inferior of natural stone. The most valuable of all the characteristics of concrete is its resistance to the action of fire, and this crowning attribute serves to emphasise the true sphere of its usefulness, *viz.*, as an inestimable structural material for the body of a building, but not for its face or ornamental features.

Returning now to the analytical aspect of the subject, it is necessary to point out that one of the most essential features of the aggregate in good concrete is cleanliness and an entire absence of dirt, dust, greasy matter and impurities of any description whatever. The material will preferably be sharp and angular, with a rough, porous surface, to which the matrix will more readily adhere than to smooth, vitreous substances. The specific gravity of the aggregate will depend upon the purpose for which the concrete is to be used. For beams and lintels, a light aggregate, such as coke breeze from gasworks, is permissible, especially when the work is designed to receive nails. On the other hand, for retaining walls, the heaviest possible aggregate is desirable on grounds of stability.

The aggregate should by no means be uniform in size. Fragments of different dimensions are most essential, so that the smaller material may fill up the interstices of the larger. It is not infrequently stipulated by engineers that no individual fragment shall be more than 4 inches across, and the material is often specified to pass through a ring, $1\frac{1}{2}$ to 2 inches in diameter. The absolute limits of size for the aggregate, however, are determinable by a number of considerations, not the least important of which is the magnitude and bulk of the work in which it is to be employed. The particles of sand should also be of varying degrees of coarseness. A fine, dust-like sand is objectionable; its minute subdivision prevents complete contact with the cement on all its faces. Another desideratum is that the particles should not be too spherical, a condition brought about by continued attrition. Hence, pit sand is better in many cases than river sand or shore sand.

The matrix is almost universally Portland cement, but as this material has formed the basis of a previous article, it is not necessary to dwell further upon its properties. It only remains to be said that the cement should not be used in too "hot" a condition, to which end it is usually spread over a wooden floor to a depth of a few inches, for a few days prior to use. By this means, the aluminate of lime becomes partially hydrated, and its activity is thereby modified. Roman cement and hydraulic lime, which may also be used as matrices, have been previously dealt with.

It now devolves upon us to take into consideration the correct proportions of the various ingredients. This is a most important matter; and it is strange, besides being regrettable, that, in many cases the composition of concrete is settled in a very haphazard manner. It is no uncommon experience to find specifications in which one part of cement is assigned to so many parts of gravel, sand, and broken stone, without apparently any systematic determination as to whether the sand and cement combined will entirely fill the interstices in the larger material, or whether again the sand is of the exact quantity required to form a trustworthy mortar with the cement. These two points call for investigation at the outset. We shall therefore proceed to deal with them.

Stated briefly, the problem before us is to determine the relative proportions of cement, sand, gravel and mineral fragments which go to form satisfactory concrete. For this purpose it is desirable to rearrange our preliminary classification, and to restrict the term "aggregate" to the coarser material, *viz.*, the gravel, broken stone and brick, etc., as the case may be. The sand and cement may now be allied as "mortar," and the main idea in the ensuing investigation will be that

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the aggregate must be thoroughly and efficiently bedded in mortar, much in the same way as stone in ordinary masonry. It is necessary, however, to point out that concrete may be made without sand, but that such a modification in its composition would entail the introduction of a far higher proportion of cement in order to fill the greater vacuities among the coarser fragments. This method, therefore, does not lend itself to economical construction.

Before going further there are two postulates to be made which are founded on actual experiment:—

(1.) That cement and sand mixed together with water diminish in volume very considerably—roughly, within the limits of ordinary mortar, by about one-fourth of their joint bulk in the separate, dry condition.

(2.) That gravel and broken stone, when intimately combined, occupy less space than they do apart. This fact scarcely needs statement, it is almost sufficiently obvious of itself, for it takes very little consideration to perceive that much of the gravel will be absorbed by the vacuities in the broken stone. In spite, however, of the absurdity of the notion, not a few people seem to entertain the fallacy that, say, two parts of gravel and four parts of broken stone make six parts of aggregate. Such would, of course, only be the case if the broken stone were as small as the gravel, a condition which is practically inconceivable. It is quite possible, and far more likely, that there would be no more than four parts of aggregate. At any rate, the exact quantity lies somewhere between the two extremes, and is a point to be determined.

Manifestly it depends very largely on the relative size and shape of the component particles. Suppose, however, we take a purely theoretical, and even fanciful case, in which the aggregate consists of a number of exactly uniform spheres or globules. It will be found that these spheres can be arranged in contact with one another in four ways of varying compactness. For simplicity's sake, we will only take the most obvious of these, of which the plan and the elevation are alike as shown in Fig. 1. If we call the radius of the spheres R, the volume of each is $\frac{4}{3}\pi R^3 = 4{\cdot}18\ R^3$; and the solid content of the cube, a section of which is shown in the diagram $= 3^3 \times 4{\cdot}18\ R^3$. The volume of the cube itself is $(6\ R)^3 = 216\ R^3$. Therefore, empty space =

$$100\left(1 - \frac{27 \times 4{\cdot}18\ R^3}{216\ R^3}\right) = 47{\cdot}64 \text{ per cent. of total space.}$$

Now if the vacuities between the spheres be occupied by smaller spheres ($r = 0{\cdot}732R$) which just touch the surfaces of the larger spheres (Fig. 2), it will be found that the percentage of empty space falls to 27·12; so that the solid content of the whole has been increased by nearly 50 per cent. without the least increase in volume. And this is what occurs, in principle, when gravel is mixed with fragments of broken stone (Fig. 3).

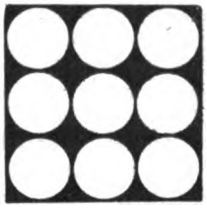

FIG. 1.

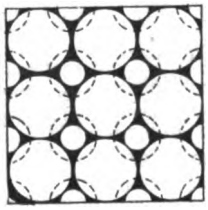

FIG. 2.

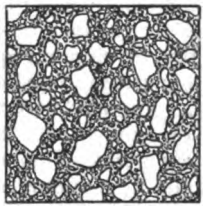

FIG. 3.

From the irregularity and angular nature of these materials, it might be supposed that their actual percentages of empty space would differ very widely from the foregoing standard. Yet such is not the case. The approximation is even so close as to be striking. Thus, the interstices in broken stone of large size, in fragments varying from 3 inches to 6 inches across, amount on an average to 50 per cent. of the gross bulk of the stone. Combined with gravel ranging in size from large peas to pebbles 2 inches or 2½ inches across, the net vacuities may be taken at about 30 per cent.

Having settled these preliminaries, we may now devote ourselves to determining the proper proportion (*a*) sand to cement and (*b*) mortar to aggregate.

The first point is settled by judgment and experience, the second by computation. Portland cement will take a larger proportion of sand than either Roman cement or hydraulic lime; but with the larger ratios of sand, its tenacity is, of course, correspondingly reduced. One part of cement to four

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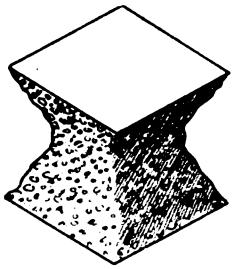

FIG. 4.

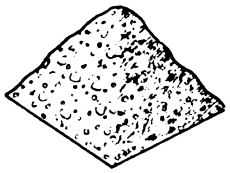

FIG. 5.

parts of sand should therefore be looked upon as the upper limit, while for the strongest mortar the proportion need hardly exceed one part of cement to one and a half or two parts of sand. In the ensuing calculations we shall strike a mean, and assume a ratio of one to three. For impermeability, the proportion of one to two should be observed, and for Roman cement this proportion should never be exceeded. The ratio will even advantageously be limited to 2 : 3. For hydraulic lime equal parts of sand and cement are suitable, though two parts of sand to one part of cement may be used.

The quantity of mortar required in reference to the aggregate is based on the vacuities in the latter. For any particular aggregate the amount of empty space may be determined by filling a tank of known volume with the minerals and then adding sufficient water to bring to a level surface. The volume of water added (provided, of course, the aggregate be impervious or previously saturated) gives the net volume of mortar required. To this, however, it is necessary to make some addition (say 10 per cent. of the whole), in order to ensure the thorough flushing of every part of the work.

Assuming that the proportion of interstices, as previously indicated, is 30 per cent., and adding 10 for the reason just stated, we derive 40 parts as the quantity of mortar to $100 - 10 = 90$ parts of the aggregate. An allowance of one-fourth volume for shrinkage brings the volume of the dry materials (sand and cement) of the mortar to $40 + \frac{40}{3} = 53\frac{1}{3}$ parts, which, divided in the ratio of 1 to 3, yields :—

Cement $\frac{53\frac{1}{3}}{4}$	= .	$13\frac{1}{3}$ parts
Sand $\frac{3}{4} \times 53\frac{1}{3}$	= .	40 ,,
Aggregate . . .		90 ,,
Total . .		$143\frac{1}{3}$,,

As the resultant concrete is 100 parts, the total shrinkage is 30 per cent. Expressed in terms of the cement, the concrete would have a composition of 1 cement, 3 sand, 7 gravel and broken stone, and it would form, approximately, what is commonly known as 7 to 1 concrete.

There are, of course, other ratios depending on the proportion of sand. Thus we have :—

Cement.	Sand.	Aggregate.
1 . .	$1\frac{1}{2}$ . .	$4\frac{1}{3}$
1 . .	2 . .	5
1 . .	$2\frac{1}{2}$ . .	6
1 . .	3 . .	7
1 . .	$3\frac{1}{2}$ . .	$7\frac{1}{2}$
1 . .	4 . .	$8\frac{1}{4}$

The cost of concrete may be very materially reduced without affecting the strength or efficacy of the work, by a plentiful use of stone "plums" or "burrs." These are bedded in the fluid concrete during its deposition *in situ*, but care must be taken to see that they are thoroughly surrounded by mortar and not in contact with each other. Furthermore, if they are of a porous nature, they should be wetted well before use.

The mixing of concrete is an important matter. If done by hand, the materials forming the aggregate will be laid out on a platform of deals and covered by the cement in a thin layer. The whole should be turned over thrice in the dry state, and as many times wet, before depositing, in order to bring about thorough and complete amalgamation.

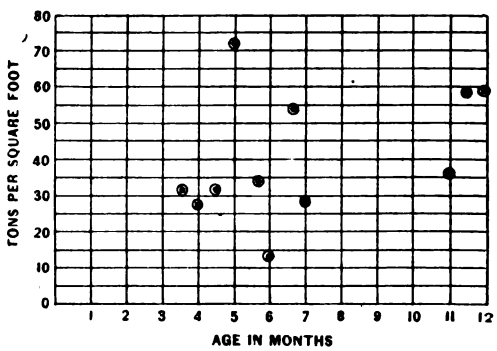

FIG. 6.—BREAKING STRESS OF CONCRETE FROM A LIVERPOOL DOCK-WALL.

Once mixed, the concrete is to be deposited immediately and allowed to remain undisturbed until the action of setting is finished. Deposition should be effected, wherever possible, without tipping from a height of more than about six feet, as in greater falls there is a likelihood of the heavier portions of the aggregate separating from the lighter.

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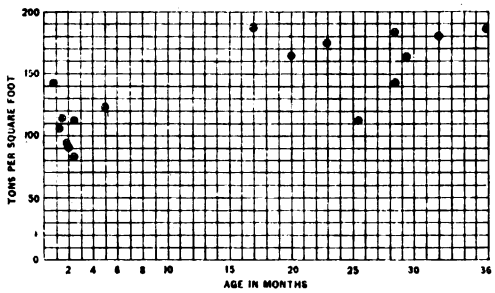

FIG. 7.—BREAKING STRESS OF CONCRETE FROM VYRNWY DAM.

In extensive undertakings, concrete is more economically mixed by mechanical appliances.

The water used for mixing may be either salt or fresh, so far as the strength of the concrete is concerned. But for surface work above the ground level, salinity in any of the ingredients is objectionable since it tends to produce efflorescence—an unsightly, floury deposit, difficult to get rid of. The quantity of water required cannot be stated with exactitude; it will depend upon the proportion of the aggregate and its porosity. It is best determined by experiment in each particular case. Without being profuse enough to "drown" the concrete, it should be plentiful enough to act as an efficient intermediary between every particle of the aggregate and every particle of the matrix. Insufficient moisture is, in fact, as deleterious as an excess.

The matter is a contentious one, and it has been the subject of considerable divergency of opinion. There are well-known authorities who advocate a very sparing use of water, and who recommend the treatment of concrete by continuous beating, so as eventually to cause moisture to appear upon its surface, in the same way as it appears upon the surface of damp sand under similar treatment. The process, however, is tedious and expensive, and it is not apparent that the results are altogether commensurate with the trouble taken to obtain them. No doubt the compressive strength of such concrete is high, but, in the majority of cases, the lower value attained without any elaborate operations is serviceable enough at a much less cost. Then, again, it is a difficult matter to gauge the exact minimum of water required, and any undue paucity fails to produce that thorough chemical action which is essential to soundness and durability. Cases have occurred in which the insufficiently hydrated particles of cement have been washed out of the pores of the concrete at a later stage when exposed after induration to the action of running water, thus leaving the work in a honeycombed and pervious condition. The writer's experience has been that a well-watered concrete, of the viscous consistency of honey or treacle, yields an excellent material, sound, durable and hard, answering all the exacting requirements of maritime engineering work.

This brings us to the question of strength. The testing of concrete is chiefly confined to a determination of its compressive strength, the use of concrete in tension being avoided in sound design. The wide range of results obtained by experiment is evidence of the very variable nature of its resistance. The method of testing is that of making small cubes, from 6 to 24 inches side, and crushing to failure. The manner in which failure takes place is somewhat striking. In the majority of cases, the cube fractures in such a way as to leave a pyramidal structure, either single or double, as shown in Figs. 4 and 5. Some typical numerical results are illustrated graphically in the ensuing figures. The set in Fig. 6 relate to concrete used at one of the Liverpool docks; the blocks, the surfaces of which were somewhat rough and not specially prepared for the testing machine, contained eight parts of gravel and sand to one of cement. There can be no doubt that with specially prepared surfaces much higher results would have been obtained. The set in Fig. 7 are values obtained by Professor Unwin from sample cubes of the concrete used in the construction of the Vyrnwy dam; its composition

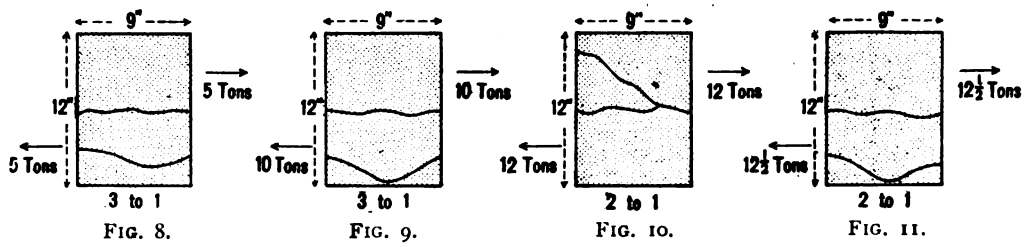

FIG. 8. FIG. 9. FIG. 10. FIG. 11.

SHEARING STRENGTH OF CONCRETE, AND NATURE OF FRACTURE UNDER SHEARING STRESS.

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was six parts of gravel and broken stone to one of cement. The latter results are very high, but still higher records afford conspicuous evidence of the careful and systematic manner in which the work was punned and consolidated. Of blocks cut out of the hearting of the actual structure, at different depths and therefore of different ages, the lowest resistance to cracking under compression was 184·4 tons per sq. ft. in the case of a block about nineteen months old, and the highest was 329·5 tons per sq. ft. in the case of a block two years old; while the mean resistance of nineteen blocks, between one and two years old, was 263 tons per sq. ft.

The effect of testing concrete in shear in a few experiments is shown in Figs. 8 to 11, as also the lines of fracture. The dimensions of the blocks tested were 9 in. by 12 in. by 12 in. The result obtained in the first case is very low and possibly due to some latent imperfection.

Concrete has also been tested, in certain instances, in regard to its transverse strength. These results, reduced to their equivalent values for a beam twelve inches square in cross section and twelve inches long between supports, are exhibited in Fig. 12. The weight given is the breaking load applied centrally.

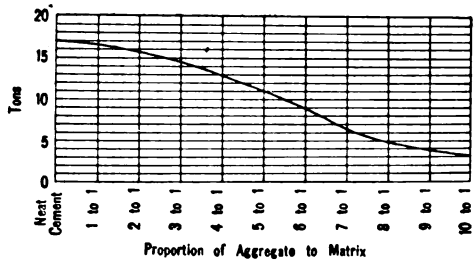

FIG. 12.—TRANSVERSE STRENGTH OF CONCRETE.

In dealing with concrete it cannot but be conceded that there are quite a number of practical points, relating to its adaptability to various situations, which would have called for notice, had it been feasible to discuss the subject at greater length. The foregoing observations, however, will suffice to cover in a general way the very many interesting issues which lie within the range of a topic of such widespread importance.

THE CLASSICS *versus* SCIENCE.

THE HON. JOHN COLLIER contributes an interesting article on the above subject to the April number of the *Cornhill Magazine*. He contends that the ordinary school is for the ordinary scholar; that the ordinary scholar has no aptitude for classical studies, and therefore derives no benefit from these, and never reads a classical author after leaving school; and finally, that the average scholar is by no means a fool, but is capable of deriving benefit from scientific and technical studies. He quotes the utterance of an eminent headmaster, who says:—

"I would undertake to tell whether a form were 'science' or 'classics,' without previous warning, by their manner of entering a classroom, their speech, and, I think, even by their appearance."

On the other hand, the Japanese some years ago, sent some of their keenest intellects to Europe, in order to determine the reasons for the superiority of Europeans. "They examined into the art, the literature, the religion, and the science of Europe, and came to the conclusion that it was the science alone that conferred the superiority, and it was the science alone that they brought back to Japan. With its aid they made themselves, in an incredibly short space of time, one of the most efficient nations in the world. . . . It may be owing to this dearth of the classics that they are not (according to our standard) as good-looking as we are, but their manners are said to be quite unaccountably refined. Is it possible that we have attached a little too much importance to our fetish?"

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART VIII.—ELECTRONS.

By EDWIN EDSER, A.R.C.Sc.

WHEN electric tubes of force move in a direction at right angles to their lengths, a magnetic field is produced; if the sectional area of each tube is such that N tubes pass normally through one square centimeter, and if the velocity of the tubes perpendicular to their lengths is equal to v centimeters per second, then the magnetic field H produced is equal to $\kappa N v$ (TECHNICS, Vol. III., No. xvi., April, 1905, p. 346). If tubes of force, such as AB, Fig. 1, are moving with a velocity v in a direction making an angle θ with their lengths, then it is obvious that the component velocity of the tubes perpendicular to their lengths is equal to $v \sin \theta$, and the resulting magnetic field will have the value $\kappa N v \sin \theta$.

Let the medium through which the tubes move possess unit permeability (*i.e.*, $\mu = 1$); then B, the magnetic induction, is equal to H, the magnetising force. In these circumstances the kinetic energy per cubic centimeter of the medium is equal to $H^2/8\pi$; substituting $H = \kappa N v \sin \theta$, we find that the kinetic energy per unit volume has the value

$$\frac{\kappa^2 N^2 \sin^2 \theta}{8\pi} v^2.$$

Now this kinetic energy must be equal to one-half the mass per unit volume, multiplied by the square of the resultant velocity v of the tubes; hence we find that the mass (or inertia) per cubic centimeter of the tubes is equal to $(\kappa^2 N^2 \sin^2 \theta)/4\pi$, and the mass per centimeter length of a single tube is equal to $(\kappa^2 N \sin^2 \theta)/4\pi$.

It thus appears that the mass (or inertia) per unit length of a tube of force depends on the direction in which the tube is moving; the inertia of the tube is greatest when the direction of motion is perpendicular to the length of the tube, and equal to zero when the tube moves parallel to its length. This result appears, at first sight, to present an alarming divergence from the known properties of moving material bodies; nevertheless, mechanical systems can be found which behave in a somewhat similar manner. Imagine a spherical bubble of air moving through a liquid; the air within the bubble possesses an extremely small mass, and yet the inertia of the bubble is considerable. This is due to the fact that the liquid in front of the bubble is being pushed forward, while that behind the bubble is flowing up in its wake; the inertia (or apparent mass) of the moving bubble is thus made up of two parts, one being equal to the mass of the air within the bubble, and the other

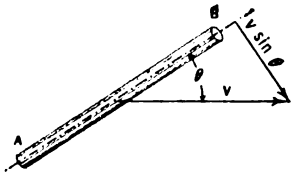

FIG. 1.—TUBE OF FORCE MOVING IN A DIRECTION INCLINED TO ITS LENGTH.

equal to the mass of the liquid carried along with the bubble. In this case the increase in the apparent mass of the bubble, due to the liquid carried along by it, is equal to half the mass of the liquid displaced by the bubble; this result will be the same in whatever direction the bubble moves. If, however, we imagine a long, narrow, cylindrical bubble to move through a liquid, it will carry scarcely any liquid with it when the direction of motion is that of the axis of the cylinder; and in this case the apparent and true masses of the bubble will be equal. If, however, the cylindrical bubble moves in a direction perpendicular to its length, a considerable quantity of the liquid will be carried along with it, and the apparent mass of the bubble will be increased by the mass of liquid displaced.

I believe that, up to the present, no satisfactory mechanical explanation of the inertia of tubes of force has been given. We have seen that the inertia per unit length of a tube is inversely proportional to the sectional area of the tube—a result that would not hold with the bubble discussed above. Professor J. J. Thomson has shown that a vortex filament moving through a fluid in a direction perpendicular to its length, carries

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a quantity of the fluid with it: in this case it appears that the mass of the fluid carried along by each vortex filament is proportional to the number of filaments per unit of area; but the mass of fluid carried forward is inversely proportional to the square of the velocity with which the filaments are moving —a result which does not agree with the properties of a moving electric tube of force.

Moving Charged Sphere.

Let us now investigate the properties of a moving sphere charged with q electro-magnetic units of electricity. Let a line through the centre of the sphere, and parallel to the direction of motion, be called the *axis* of the sphere; and let the points where this axis cuts the surface of the sphere be called the *poles*, while a plane through the centre of the sphere, and perpendicular to the axis, is called the *equatorial plane*. If the charged sphere were stationary, its tubes of force would radiate uniformly from it; let us assume that they still do so when the sphere is in motion. At a point A (Fig. 2) in the equatorial plane, at a distance r from the centre of the sphere, the electric field (force per unit charge) will be equal to $q/(\kappa r^2)$ (Technics, Vol. II., No. x., October, 1904, p. 362). But, by definition, the force per unit charge is equal to N, the number of electric tubes of force per square centimeter (Technics, Vol. II., No. xii., December, 1904, p. 575); hence $N = q/(\kappa r^2)$. The tubes in the equatorial plane will obviously be moving perpendicular to their lengths, with the velocity v imparted to the sphere; hence the magnetic field (force per unit N pole) at A is equal to—

$$\kappa N v = \kappa \frac{q}{\kappa r^2} v = \frac{qv}{r^2} \quad . \quad . \quad . \quad (1)$$

Equation (1) shows that the magnetic field is constant in magnitude for all points in the equatorial plane at a given distance r from the moving charge. If we suppose an electric current to flow along the direction of motion of the charge, the electric tubes of force associated with the current will move through the point A, just as those due to the positive charge carried by the sphere do. If the moving sphere be replaced by a current C flowing along a short length l of a conductor lying along the position previously occupied by the axis of the sphere, the field at H will be equal to $(Cl)/r^2$; hence we see that the moving charge produces the same magnetic field as a current-element Cl equal to qv at the centre of the sphere. Further, the magnetic field at A will be directed upwards through the plane of the paper, and the lines of magnetic force will be circular, directed in a clockwise sense when looked at in the direction of motion of the charge.

If a unit N pole were placed at A (Fig. 2), the force acting on it would be equal in magnitude but opposite in direction to the reaction produced on the moving sphere; hence (1) gives us the force acting on a sphere charged with q electro-magnetic units, and moving with a velocity of v cms. per second, when a unit N. pole is placed at a distance r from its centre, and in the equatorial plane of the sphere. The magnetic field H at a distance r from the unit N. pole will, of course, be equal to $1/r^2$; hence the force acting on the sphere

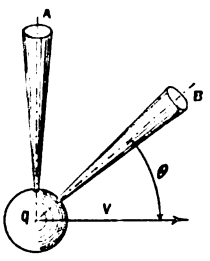

Fig. 2.—Charged Sphere carrying its tubes of force with it.

$$= \frac{1}{r^2} qv = Hqv \quad . \quad . \quad . \quad (2),$$

where H is the magnetic field at the centre of the sphere. Hence, if a charge q moves with a velocity v at right angles to a magnetic field H, the force on the charge is equal, in magnitude and direction, to that acting on a current element $Cl = qv$ coinciding with the axis of the sphere; in particular, the force acting on the position charge q in Fig. 2 will urge the sphere downwards through the plane of the paper. Further, if we reverse the sign of either q or v we reverse the direction of the force acting on the moving charge; if we reverse the signs of both q and v the direction of the force is unaffected.

At the point B (Fig. 2) the magnetic field will be equal to $\kappa N v \sin\theta = (qv \sin\theta)/r^2$, where r is the distance from B to the centre of the charge.

Let us now determine the inertia of any tube of force inclined at an angle θ to the direction of motion of the charge. Let there be N tubes per square centimeter at B. If the tube were everywhere of the same section as at B, its inertia would be equal to $(\kappa^2 N \sin^2\theta)/4\pi$ multiplied by the length of the tube. However, as we pass along the tube away from the charge the value of N diminishes. At a distance r_1 from the charge N is equal to $q/(\kappa r_1^2)$, while at a slightly greater distance r_2 from the charge N will be

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equal to $q/(\kappa r_2^2)$. Thus for the short length of the tube of length $(r_2 - r_1)$, lying between the above limits, the *average* value of N may be taken as $q/(\kappa r_1 r_2)$, and the inertia of this part of the tube will be equal to—

$$\frac{\kappa^2 \sin^2\theta}{4\pi} \cdot \frac{q}{\kappa r_1 r}(r_2 - r_1) = \frac{\kappa \sin^2\theta}{4\pi}\left(\frac{q}{r_1} - \frac{q}{r_2}\right)$$

An expression for the inertia of the next element of the tube, lying between the distances r_2 and r_3 from the charge, can be readily written down, and so on for the other elements of the tube. Let us suppose that the radius of the sphere is a cms., while a tube extends to a distance R from the charge; then, dividing this tube into short elements, writing down the value of the inertia of each, and adding all together, we find that the inertia of the tube is equal to—

$$\frac{\kappa q \sin^2\theta}{4\pi}\left(\frac{1}{a} - \frac{1}{R}\right);$$

if R is very great in comparison with a, we may neglect $1/R$, in which case the inertia of the tube will be equal to—

$$\frac{\kappa q \sin^2\theta}{4\pi a} \quad . \quad . \quad . \quad (3)$$

When the charged sphere is set in motion, its inertia will be increased by the inertia of the tubes of force which are carried along with it. In finding the value of this increase of inertia, we must first find the number of tubes leaving a circular strip of the surface of the sphere at an angle θ, and then multiply this into the inertia of each of the tubes, given by (3). On performing this operation for all values of θ between 0 and π, and adding the results together, we find* that the total increase in the inertia of the sphere, due to the tubes carried along by it, is equal to—

$$\frac{2q^2}{3a} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Thus the inertia of the tubes of force carried by the sphere is proportional to the square of the charge, and inversely proportional to the radius of the sphere.

In the above investigation it has been assumed that the positions of the tubes of force relative to the moving sphere are identical with those occupied by the tubes of force when the sphere is at rest. This assumption introduces no appreciable error if the velocity of the sphere is not very great in comparison with the velocity of light; but for high velocities the tubes crowd up toward the equatorial plane, so that they all move, as nearly as possible, in a direction perpendicular to their lengths, and therefore possess as great an inertia as possible. If the spheres were moving with the velocity of light, the tubes would all crowd up into the equatorial plane; their sectional areas would then become equal to zero, and their inertia would become infinite. Hence it appears that a charged sphere moving with the velocity of light would possess an infinite store of energy: it could not be stopped by any finite force, nor could it be set in motion with the velocity of light by the application of any finite force.

The tendency of the tubes of force to crowd up toward the equatorial plane as the velocity of the sphere increases is due to the fact that each tube tends to set itself so as to possess as much inertia as possible. It has previously been explained that a long thin cylinder moving through a liquid carries a considerable quantity of liquid with it when moving in a direction at right angles to its length, and carries no liquid with it when moving parallel to its length. It is known that a cylinder moving through a liquid always tends to set itself at right angles to the direction of its motion; thus, if a cylindrical bullet is fired from a gun that is not rifled, the bullet sets itself at right angles to its direction of motion, and modern guns are rifled to prevent this action. For similar reasons, when a leaf or a sheet of paper falls through the air, it sets itself broadside on to the direction of its motion; a penny dropped into water behaves in a similar manner.

The principles deduced above have been used to explain the phenomena attending the discharge of electricity through a rarefied gas. A brief account of these phenomena and the results deduced from them will now be given.

Vacuum Tube Phenomena.

When an electric discharge passes through a rarefied gas many beautiful phenomena are produced. The appearances presented by the discharge can be explained by the diagrammatic sketch (Fig. 3), which represents a closed tube in which the gas has been reduced to a pressure of a fraction of a millimeter of mercury; the electrodes by way

Fig. 3.—Diagrammatic Representation of Phenomena produced in highly exhausted vacuum tube.

* The solution of this problem, which involves a simple application of the Integral Calculus, will be found on p. 475 of this issue.

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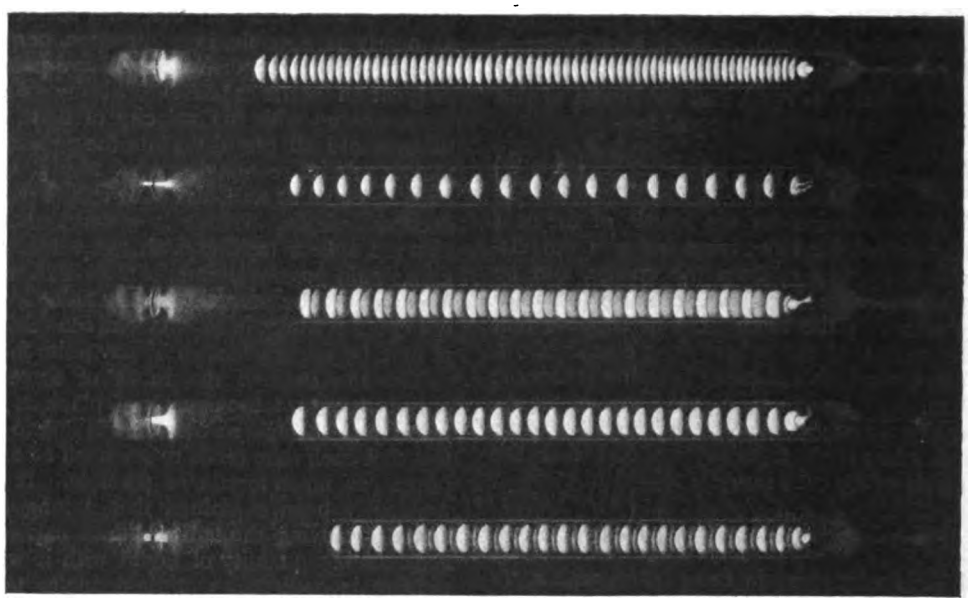

FIG. 4.—TO ILLUSTRATE THE DISTINCTIVE FEATURES OF AN ELECTRICAL DISCHARGE IN A RAREFIED GAS. (De la Rue and Müller.)

Kathode (a ring of platinum wire) to the left; anode to the right. Tube charged with hydrogen. Continuous discharge from battery of chloride of silver cells.

a. Pressure 0·2 mm. of mercury; 3,600 cells used. 61 blue strata in positive column.
b. Same as (*a*), but with 700,000 ohms in series with tube. 18 pink strata.
c. Same as (*b*), but after the lapse of some time. 21 intensely blue strata, with a carmine line between each pair.
d. Same as (*c*), but with 900,000 ohms in series with tube. 26 pink strata.
e. Pressure 0·518 mm.; 2,400 cells. 19 blue, saucer-shaped strata; at times fainter intermediate strata appeared.

of which the discharge enters the gas being discs of platinum or aluminium. Near the negative electrode (or kathode) is a perfectly dark space called the "Crookes dark space." This space extends from the kathode to a distance which increases as the pressure of the gas within the tube is diminished. The kathode itself is surrounded by a restricted luminous glow which gives the metal disc the appearance of being white hot.

Beyond the Crookes dark space is a luminous region, sharply defined on the side facing the kathode, and fading off at the opposite side. This luminous region is called the "negative glow."

Beyond the negative glow is a second dark space, called the "Faraday dark space." This is succeeded by a luminous column, often presenting definite stratification, which extends right up to the positive electrode (or anode); this is called the "positive column." The steadiness of the stratification in the positive column depends on the current passing through the tube. Thus, when the stratifications are unstable, or badly developed, they can often be rendered distinct by inserting a resistance in series with the tube. The exact appearance of the positive column is shown in Fig. 4, from a paper by De la Rue and Müller, published in the Philosophical Transactions of the Royal Society, Part I., Vol. 169, 1878. Each stratification is brightest and most sharply defined on the side facing the kathode, and fades away on the opposite side. For high pressures the stratifications are very numerous, each being very narrow. As the pressure is diminished the stratifications become fewer and broader (Fig. 5). The stratifications are often brilliantly coloured, and in some cases several distinct sets of stratifications of different colours can be observed in the same tube (Fig. 4, *c* and *e*). Sir William Crookes observed three sets of stratifications in a tube containing rarefied hydrogen, their colours being red, blue, and grey. Spectroscopic examination of the light emitted by these showed that the red light from the first gave the spectrum of hydrogen, the blue light from the second gave the spectrum of mercury, and the grey light from the third gave the spectrum of hydro-carbons. The dimensions of the first and second dark spaces, and the negative glow, are only slightly

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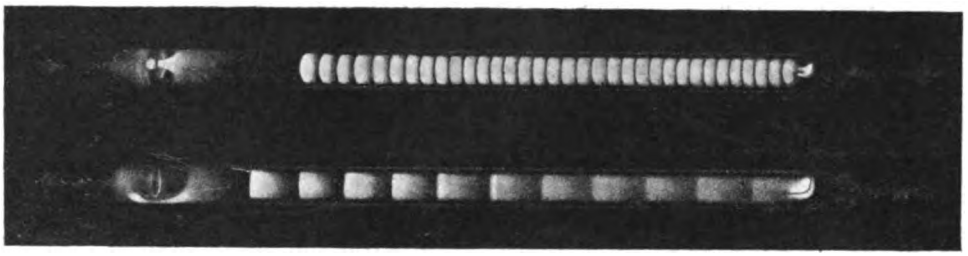

FIG. 5.—TO ILLUSTRATE THE EFFECT OF DIMINISHED PRESSURE ON THE STRATIFIED POSITIVE COLUMN. (De la Rue and Müller.)

Tube contained hydrogen.

a. Pressure 0·1204 mm. of mercury. 3,600 cells. Current 0·0177 ampere.
b. Pressure 0·051 mm. of mercury. 4,800 cells. Current 0·0019 ampere.

Notice the increase in the size of the Crookes dark space round the kathode ring, due to the diminution of pressure.

affected by the length of the tube, and the remaining space is always occupied by the positive column. Fig. 6 (also from De la Rue and Müller) represents a vacuum tube provided with a movable kathode connected by means of a coil of wire with the negative terminal of the tube. It will be seen that increasing the distance between the anode and kathode merely increases the length of the positive column, the stratifications in this remaining uniform in dimensions but increasing in number.

Kathode Rays.—Much attention and many ingenious experiments have been devoted to the determination of what occurs in the Crookes dark space. In the first place, the dimensions of this space increase as the pressure of the gas in the tube is diminished; when the pressure is so low that the Crookes dark space extends to the walls of the tube, those

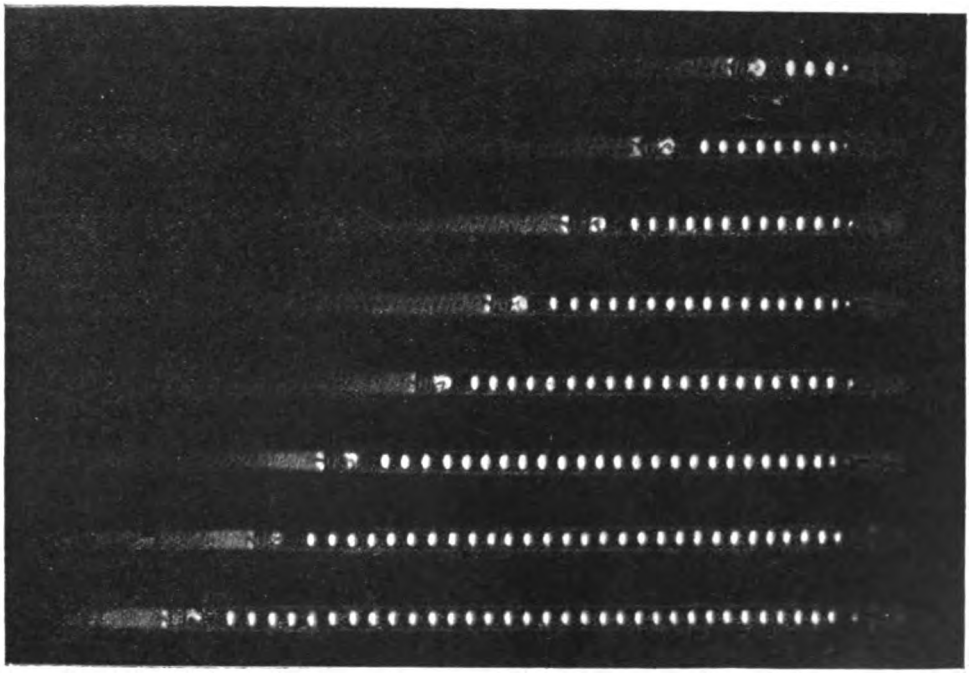

FIG. 6.—APPEARANCE OF DISCHARGE IN VACUUM TUBE WITH MOVABLE KATHODE. (De la Rue and Müller.)

Tube 56 inches long, and 1·375 inch diameter, containing carbon dioxide. The kathode is shown to the left in eight different positions, the only differences in the effects produced being that the greater the distance between kathode and anode, the greater is the number of stratifications in the positive column.

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parts of the glass which are reached by the dark space become fluorescent, emitting light of a colour depending on the nature of the glass: the light emitted by sodium glass is yellowish-green, while that emitted by lead glass is blue. Precious stones (such as the diamond) and the alkaline earths become fluorescent when placed in the Crookes dark space.

If the pressure of the gas within the tube is sufficiently low, the Crookes dark space occupies the whole of the tube; in this case the whole of the walls of the tube become fluorescent. If an obstacle is placed in front of the kathode (Fig. 7) a well-defined shadow is cast on the walls of the tube. This indicates that the fluorescence is produced by some form of radiation emitted by the kathode;

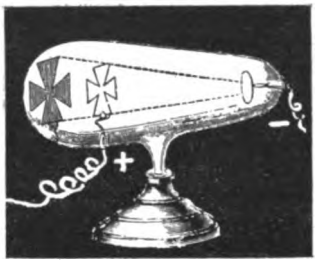

FIG. 7.—TO ILLUSTRATE SHADOW THROWN FROM AN OBSTACLE BY KATHODE RAYS.

the name "kathode rays" has been applied to this radiation. It appears that the glass of the tube becomes "fatigued" and fluoresces less brightly after protracted exposure to the kathode rays. The cross shown in Fig. 7 is hinged, so that it can be shaken down into a position in which it no longer casts a shadow; and if this is done after the kathode rays have played for some time on the walls of the tube, the part of the glass previously in shadow is more brightly luminous than the rest of the tube. Sir William Crookes has found that when the glass of the tube is melted and formed into another tube, the fatigue of the glass still persists.

If the kathode has the form of a fairly large disc, and a small object is placed just in front of this, a fairly well-defined shadow is cast on the walls of the tube. This shows that the kathode rays are emitted normally from the kathode; if they were emitted like light proceeding from a luminous disc, no appreciable shadow would be cast under these conditions, as can easily be proved by trying to obtain a shadow from a small object placed near the flame of a bat's-wing burner.

A stream of material particles impinging on a surface would exert a definite pressure on this. Similarly, the kathode rays exert a pressure on any surface on which they impinge; this is very conclusively proved by the apparatus represented in Fig. 8, which represents a highly exhausted vacuum tube containing a small wheel with mica vanes, the wheel being capable of rolling on its axle along two glass rails. On exciting the tube, the kathode rays from the negative electrode fall on the upper vanes of the wheel, and cause them to rotate in the direction shown by the arrow, so that the wheel rolls from one end of the tube to the other.

Sir William Crookes also found that if the kathode rays are allowed to fall on a thin piece of platinum foil, so much heat is produced by their impact that the foil may be raised to incandescence, or even melted.

Kathode rays are deflected when they traverse a magnetic field in a direction at right angles to the lines of force. This can be proved by placing two metallic cylinders B and C, with horizontal slits in a line with each other, in front of the kathode K (Fig. 9); the kathode rays then cause a horizontal strip of the glass at P to become fluorescent. If we now produce a strong magnetic field in the space traversed by the rays after they have passed through the two slits, the luminous patch on the glass moves to Q if the magnetic lines of force pass downwards through the plane of the paper. A similar deflection would obviously be produced in a flexible conductor carrying an electric current from right to left in Fig. 9. From the results previously deduced with relation to moving charges, a similar deflection would be produced in a stream of positive charges moving

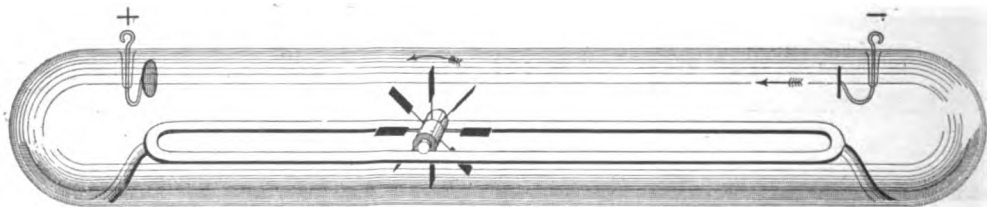

FIG. 8.—TO ILLUSTRATE THE PRESSURE PRODUCED WHEN KATHODE RAYS FALL ON AN OBSTACLE.

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from right to left, or a stream of negative charges moving from left to right; as the kathode rays obviously proceed from left to right in Fig. 9, we may conclude that if these rays consist of streams of charged particles, these particles must carry negative charges.

That the kathode rays do carry negative charges has been proved experimentally. A vacuum tube (Fig. 10) is used, which has a side tube containing a hollow metal cylinder C with a hemispherical end provided with a small opening; this cylinder is connected to earth by means of a wire connected to the terminal E. A metal sphere D is supported

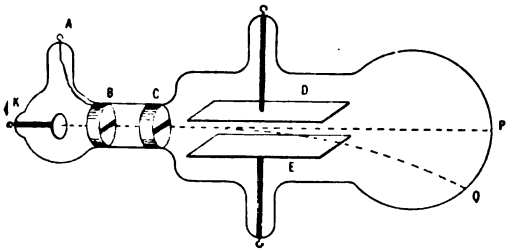

FIG. 9. — APPARATUS USED FOR DETERMINING THE RATIO OF THE CHARGE TO THE MASS OF A KATHODE RAY PARTICLE.

within the cylinder, from which it is insulated; this sphere is connected to a terminal F from which an insulated wire extends to one pole of a quadrant electrometer of which the other pole is earthed. The kathode rays from the negative electrode K pass through a small axial hole in a cylinder A, and a spot on the glass in line with this hole is rendered luminous. By the use of a magnet the kathode rays may be deflected so as to fall on any required part of the tube; when they pass through the opening of the cylinder C and fall on the sphere D the electrometer indicates that a negative charge has been imparted to D. After the rays commence to fall on D the deflection of the electrometer at first steadily increases; after a time, however, it becomes constant. If, before performing the experiment, the sphere D is charged to a high negative potential, on allowing the kathode rays to fall on D the potential diminishes till the deflection of the electrometer is the same as that finally produced when the charge is only imparted by the kathode rays. This indicates that the kathode rays render the gas within the tube conducting, so that the highest potential imparted to D corresponds to the state in which the charge lost per second, owing to the conductivity of the gas, is just balanced by the charge communicated per second by the kathode rays.

It thus appears that the kathode rays consist of streams of negatively-charged particles; it has been found possible to determine the speed of these particles, their masses, and the charge carried by each. The way in which these results have been achieved will now be described.

Speed of Particles, and Ratio of Charge to Mass.—In Fig. 9, let the charge carried by each particle moving from left to right be numerically equal to q, and let v be the velocity with which each charge is moving. If the magnetic field at right angles to the path of the particles has the value H, the force acting on each particle will be equal to Hqv (p. 422). This force will cause the particle to move with undiminished velocity in an arc of a circle, and to strike the walls of the tube at Q instead of P. By observing the displacement P Q of the luminous spot on the tube, the radius of curvature of the path of the particle can be determined. If this radius is equal to r, and the mass of the particle is equal to m, the centrifugal force acting on the particle must be equal to mv^2/r; and as this must be just balanced by the force due to the action of the magnetic field on the particle, we have

$$Hqv = \frac{mv^2}{r};$$

$$\therefore \frac{q}{m} = \frac{v}{Hr} \quad . \quad . \quad . \quad (5).$$

The value of v can be found as follows:—

The tube represented in Fig. 9 is provided with two parallel plates D, E, placed so that

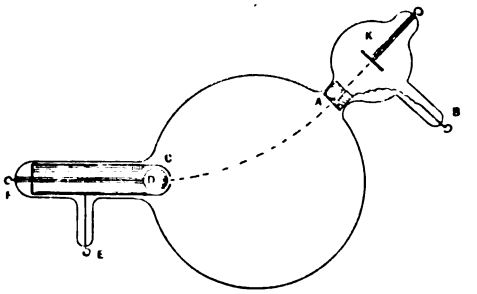

FIG. 10.
APPARATUS USED FOR SHOWING THAT KATHODE RAY PARTICLES CARRY NEGATIVE CHARGES.

the kathode rays pass between them. Let a magnetic field of value H_1 be maintained only in the space between the plates, the direction of the field being downwards through the plane of the paper; this will tend to deflect the moving particles so that

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they strike the tube on the same side of P as Q. If the plate D is charged positively and the plate E negatively, the electric field (force per unit charge) between them being equal to F, then the negatively charged particle will experience a force Fq tending to deflect it so as to strike the tube on the side of P opposite to Q. By adjusting H_1 and F the magnetic and electrostatic forces on the particle can be made to balance each other; in this case the particle will still strike the tube at P, and

$$H_1 qv = Fq, \text{ and } v = \frac{F}{H}.$$

Since F and H_1 can be accurately determined, the value of v becomes known; on inserting this value in equation (5), the value of the ratio q/m is determined.

In 1897 Professor J. J. Thomson applied the method which has just been outlined to the determination of the ratio q/m for the kathode ray particles in vacuum tubes containing minute traces of hydrogen, carbon dioxide, and air; in all cases he found the value of q/m to be equal to $7 \cdot 7 \times 10^6$. Now, in ordinary electrolysis the ratio q/m gives us the charge carried by a gram of a substance; if we apply this to hydrogen, which will give the largest value for the ratio q/m, we find this to be equal to 10^4. We may therefore assume the charge carried by a kathode ray particle to be about 770 times as great as that carried by a hydrogen atom, both having equal masses; or the mass of the kathode ray particle may be assumed to be only 1/770 of the mass of a hydrogen atom; both having equal charges. Researches which will be described subsequently indicate that the charge carried by a kathode ray particle is equal to that carried by a hydrogen atom in ordinary electrolysis: hence, it follows that the mass of a kathode ray particle is only 1/770 of the mass of a hydrogen atom. Many years ago Sir William Crookes contended that the phenomena observed in highly-exhausted vacuum tubes indicated the existence of a *fourth state of matter*—a state which comes under none of the titles solid, liquid, or gaseous. Professor J. J. Thomson's researches have given us quantitative evidence pointing to the existence of this state. The small particles which carry the charges in the kathode rays are called *corpuscles* by Professor J. J. Thomson, but they are commonly known by the name of *electrons*, given to them by Professor Johnstone Stoney. At the present time our knowledge of these ultra-atomic particles is not solely derived from the experimental data previously described, but a further discussion of their properties must be deferred to the next article.

(*To be continued.*)

INCANDESCENCE OF GAS MANTLES.

H. Bunte (*Jour. Gasbeleucht.* 1904, 47, 1), concludes from spectrophotometric experiments on light emitted at different temperatures by a series of mixtures of thorium and cerium oxides, that thorium oxide acts merely as a support for the particles of cerium oxide which are the true light-emitting agents, and rejects the catalytic theory. The cerium oxide is maintained at a high temperature in the flame owing to its distribution and to its being present in only small quantities; its illuminating action is a consequence of selective radiation. V. B. Lewes (*Jour. Gas Lighting*, 1905, 89, 161) draws from his experiments the conclusion that thoria, on account of its non-conductivity, low specific heat and low heat-emissivity, acquires the temperature of the flame. Ceria, by its great catalytic power, localises the combustion on the surface of the mantle, the particles of ceria being raised to a higher temperature than the mantle. When more than 1·5 per cent. of ceria is present, the heat-emissivity of the mantle is increased so much that both mantle and flame are cooled by radiation and the illuminating power falls.

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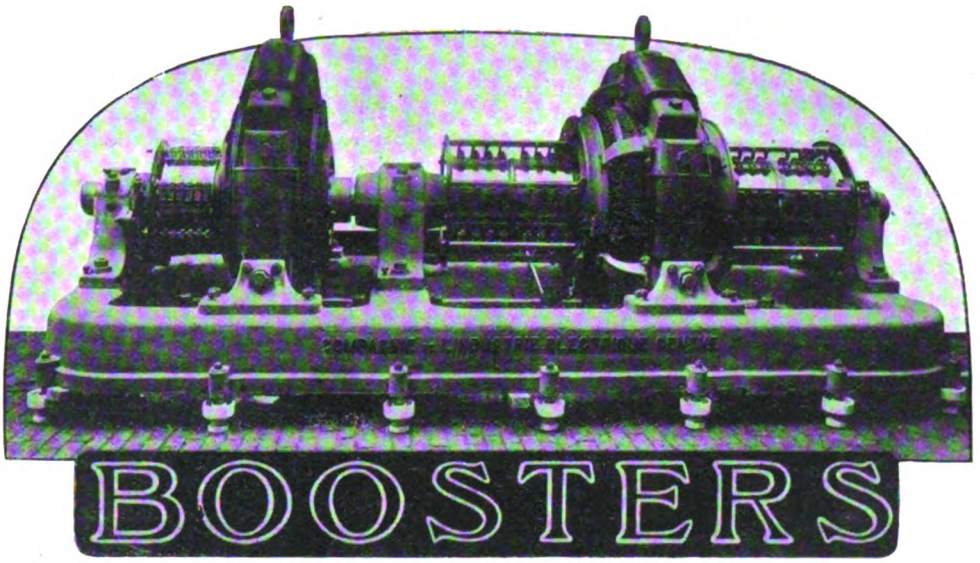

PART IV.

By HAROLD H. BROUGHTON.

IN connection with the Lancashire booster, we purpose to give a few details which cannot fail to be of interest. Briefly stated, the properties of this booster are as follows :—

1. It automatically and instantly compensates for all variations of the battery volts.

2. Its action is independent of the characteristic of the main generator, and the booster will work with either shunt or compound machines.

3. The working of the booster is controlled by the main generator current, and not by the feeder current.

4. The windings are easily adjustable by diverters and rheostats, so that the machine may be adjusted to the particular work that it is called upon to do at various parts of the day.

On (3) depends the great stability of the Lancashire booster, in actual working. Owing to the fact that the working is controlled by the generator current, instead of by the volts or feeder current, the effect is to keep the generator current approximately steady. Any sudden rush of current is taken by the battery, while as soon as the feeder current goes below the output of the generator, the battery begins to charge up again. It is also possible—if desired—to arrange for the generator current to vary so that an overload is partly taken by the generator, and partly by the battery. This enables the battery to be of a smaller size, and in actual practice is a very valuable property.

It is also possible to adjust the booster so that it will not overcharge the battery at more than 200 amperes ; this has been very successfully managed, as will be seen from Fig. 28, although the discharging current goes to nearly 500 amperes.

When the booster is working with a generator, it is possible to adjust the 'bus-bar volts just as if the booster was not there, as variations of the 'bus-bar volts are instantly taken up and met by the automatic action of the booster. It is further quite unnecessary to use reverse-current circuit-breakers, even with compound-wound dynamos, as the booster works in such a way as to prevent any current from coming back to the bars. The booster can also be run with the battery only, to take any early morning slack load ; when so run, it will compensate for the variations of the battery volts as these alter with the load.

The company have recently built a large booster for Durban, with an output as follows :—

Shunt motor running off 550 volts at 700 revolutions per minute. The booster is capable of giving 360 amperes at 140 volts

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continuous charging current, or 500 amperes at 70 volts for six hours, or 750 amperes at 110 volts for one hour, all of these with a temperature rise of 70°F. The maximum discharging current of this set is 900 amperes at 70 volts for short periods, say a quarter of an hour.

SPECIFICATION OF TRACTION TYPE, LANCASHIRE AUTO-REVERSIBLE BOOSTER.

Field Magnets.—The field magnets are laminated throughout, both magnet limbs and yoke being built up of high permeability sheet iron plates. The yoke plates are firmly fixed in a cast iron frame, and the magnet limbs are built up between brass end plates, and fastened in place by bolts passing through the yoke. This construction enables the field coils to be easily removed if necessary.

by distance pieces and internal air ducts in the core to ensure cool running. The plates are securely keyed to a cast-iron sleeve, which greatly increases the rigidity of the shaft. The commutator is also carried on this cast-iron sleeve. The windings are of the cylindrical barrel type. Each coil or bar is wound on a special former, afterwards taped up, and then dipped in a special insulating compound and dried. A trough of prepared insulation is next put into the slot, and the coil or bar slipped into position; after all the conductors are in place, fibre strips are driven into the tops of the slots, and steel bands wound tightly on, and soldered up. The bands are carried in recesses in the core, so that in case the armature touches the fields it is not damaged. The coils or bars are provided with a cast-

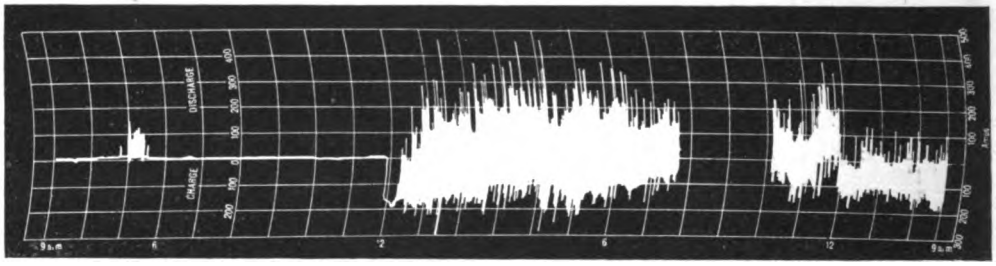

FIG. 28.—BATTERY CURRENT RECORD, NORTH SHIELDS TRACTION STATION.

Field Coils.—The field coils are former wound, insulated with press-spahn served with tape, and then dipped in an insulating compound and thoroughly baked. Each coil is provided with its own terminals, so that no loose wires project, thus avoiding the danger of the latter being broken off. The coils are held in place by brass plates, enabling air to circulate freely both inside and outside the coil, and ensuring cool running and absence of sweating; very high insulation resistance is obtained by this method, eliminating the danger of the coils earthing if the shunt current is interrupted. The series coils are of bare copper strip, wound on edge, and taped over all.

Bearings.—The bearings are of the spherical-seated, self-oiling type, each being provided with two brass oil-rings, which dip into the well below. The pedestals are of liberal dimensions, and are fitted with brass oil-gauge and tap for running off the oil.

Armatures.—The armatures are of relatively large diameter, with a small armature reaction, and are built up of thin, varnished plates, provided with slots to receive the windings. The armature is further ventilated

iron support at each end to prevent oil or dust getting into the windings. Double oil-throwers are provided to prevent any oil leaking into the armature or frame of the machine. Equalising rings are fitted on parallel wound armatures, and these may, if desired, be put on after the machine is erected, and electrically balanced.

Commutators.—The commutators are built up under hydraulic pressure, and are made of hard-drawn copper bars of liberal depth, insulated with specially selected built up mica, which wears evenly with the bars. Micanite is used for insulating the end rings.

Shafts.—The shafts are of the best mild

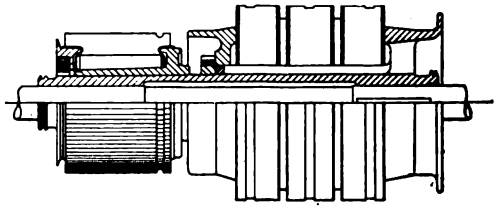

FIG. 29.
TO ILLUSTRATE CONSTRUCTION OF ARMATURE, LANCASHIRE DYNAMO CO.'S BOOSTER.

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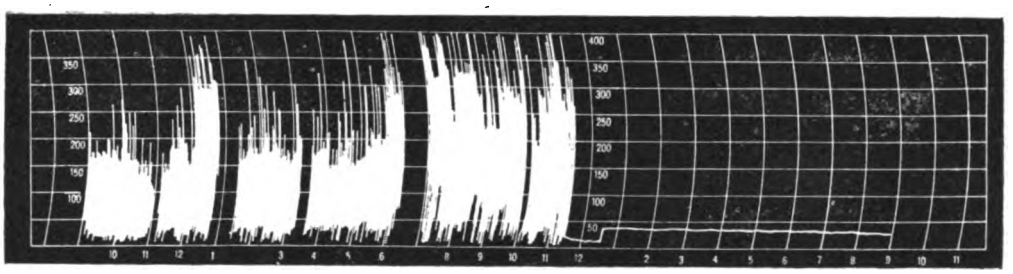

FIG. 30.—LOAD CURVE OF TRACTION FEEDER, NORTH SHIELDS TRACTION STATION.

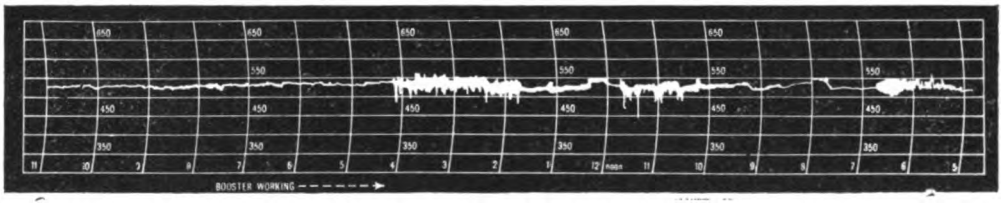

FIG. 31.—VOLTAGE RECORD, NORTH SHIELDS TRACTION STATION.

steel, accurately ground at the necks by an emery wheel. Special attention has been paid to the design, so that it is impossible for oil to creep to the armature or to the commutator.

Brush-holders.—The brush-holders are of the McLeod patent type, and consist of light stampings in which the carbons are carried; the current density on the latter does not exceed 30 amperes per square inch. The necessary pressure is given by flat steel springs possessing a wide range of even pressure. Means are provided so that the tension can be readily adjusted, and a suitable flexible copper strip carries the current from the moving to the fixed part. The holder is kept off the commutator when pulled back by the spring itself. The brush-holders are carried by a special casting, which supports both ends of the steel spindle. This casting is covered with special insulation moulded on at one end, and secured in a suitable clamp, so that it can be readily withdrawn from the machine. The brushes cover the whole width of the commutator, and can be readily adjusted in this direction by the clamp. High-class carbons only are used.

Motor.—The motor is built to the same specification as the booster, with the exception of the field magnets, which are of high grade cast steel fitted with laminated pole shoes.

Guarantee.—Should any defect occur in the machine within the period of twelve months after leaving the works, due to defective design, materials, or workmanship, the makers undertake to repair and make good the defect at their own expense.

The construction of the armature will readily be understood from an inspection of Fig. 29, from which will be seen the excellent oil-throwing arrangements, and other good features, which characterise the work turned out by this firm. The general arrangement

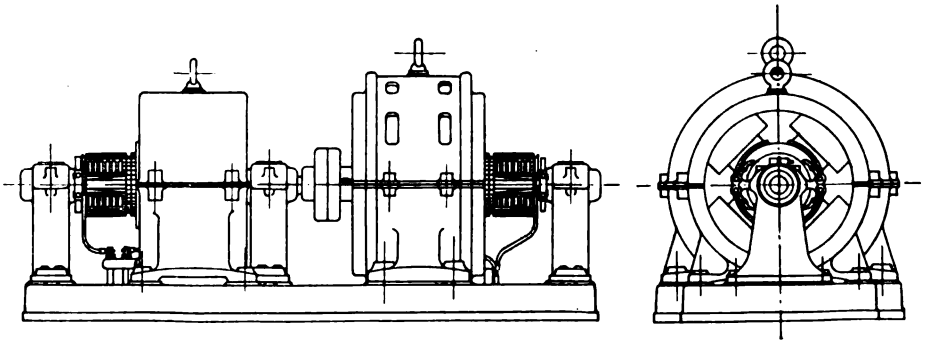

FIG. 32.—DIAGRAM OF LANCASHIRE DYNAMO CO.'S BOOSTER.

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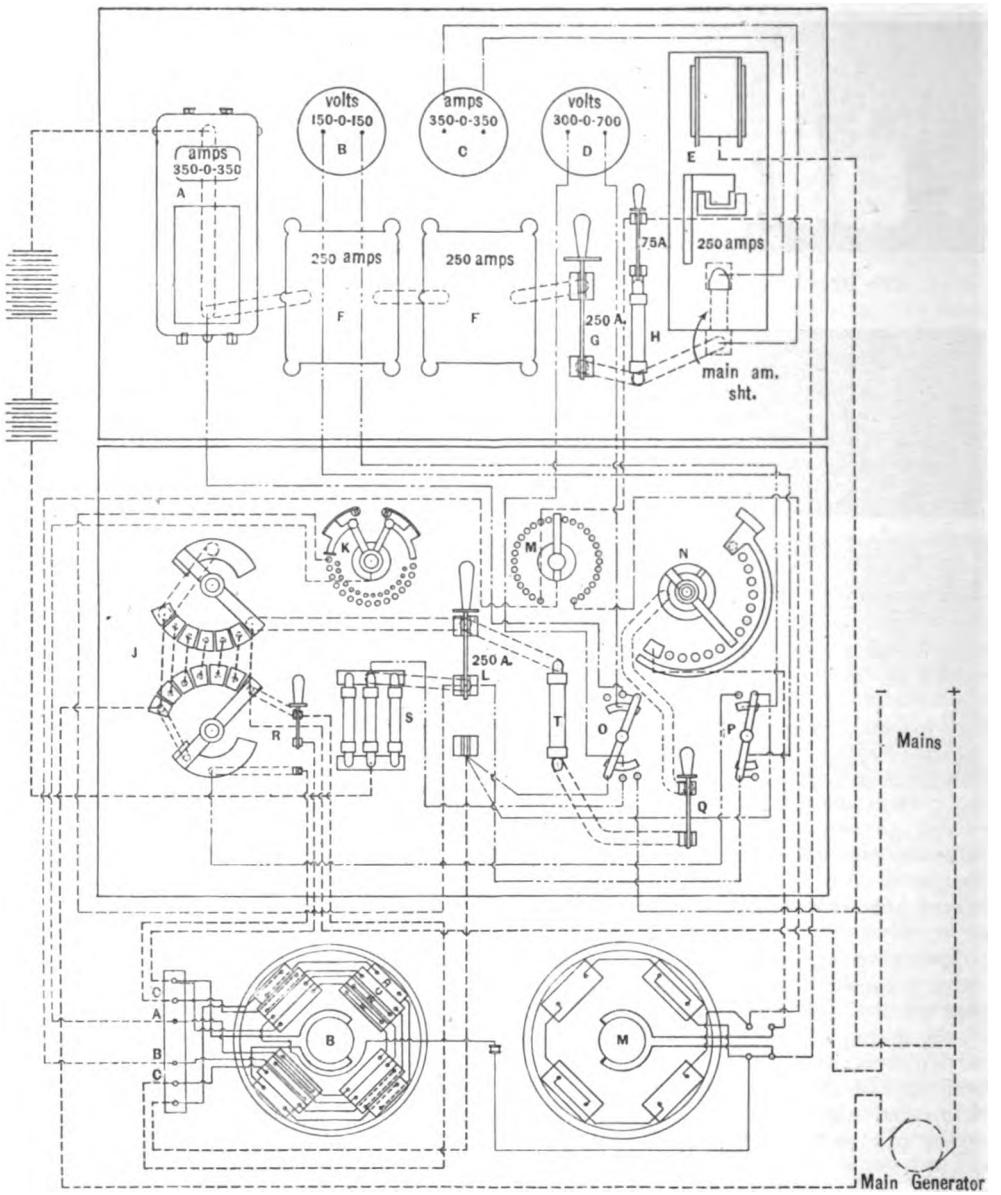

FIG. 33.—STANDARD BOOSTER PANEL, LANCASHIRE DYNAMO CO.

A. One recording ammeter, having a range of 350–0–350 amperes.
B. One booster voltmeter, having a range of 150-0-150 volts.
C. One main ammeter, with a range of 350–0–350 amperes.
D. One main voltmeter, with a range of 300–0–700 volts.
E. One 250-ampere circuit breaker.
F. Two Chamberlain and Hookham type meters for 250 amperes.
G. One 250-ampere single pole quick-break switch.
H. One 75-ampere single pole quick-break switch and fuse.
J. One regulator.
K. One field regulator and shunt breaking switch.
L. One 250-ampere single pole change-over switch.
M. One field regulating switch.
N. One motor starter.
O. One three-way voltmeter switch.
P. One two-way voltmeter switch.
Q. One 75-ampere single pole quick-break switch.
R. One single pole change-over switch.
S. One 250-ampere single pole "No Arc" fuse.
T. One 75-ampere single pole "No Arc" fuse.

of this set is shown in Fig. 32; and the standard switchboard panel in Fig. 33. At first sight this diagram appears to be very complicated, but the reader will have little difficulty in reducing this to the elementary form shown in Figs. 25 and 27.

The curves given in Figs. 28, 30, and 31 are from the North Shields traction station,

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and illustrate very clearly the properties of the machine.

The Thury Booster.—This booster differs considerably from those of other makes; the armature is of the channelled core type, having channels about three millimeters deep, semi-circular in shape, each channel receiving one wire only; the conductors are held in position by driving horns. It is claimed that this construction prevents sparking under working conditions, and also assists the booster to answer instantaneously to the heavy and sudden load-variations on the line. The field coils are tangential to the armature, the winding of which is, as already stated, placed as near as possible to the periphery; the field iron is reduced to a minimum, which considerably lessens the magnetic inertia, thereby ensuring prompt action of the booster.

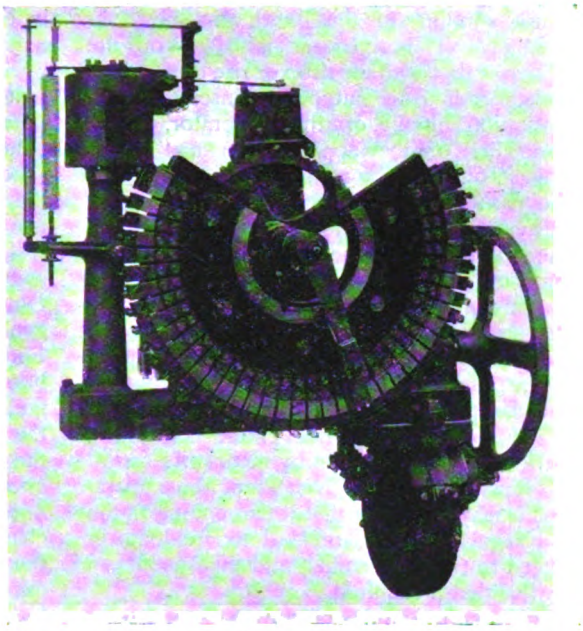

FIG. 34.—AUTOMATIC PRESSURE REGULATOR, USED WITH THURY BOOSTER.

The set consists of a shunt-wound motor fed from the 'bus-bars, directly coupled to a differentially excited booster; the series coils of the latter are in the charging circuit, and the shunt coil is in circuit across the battery terminals. The construction of the automatic pressure regulator in series with the

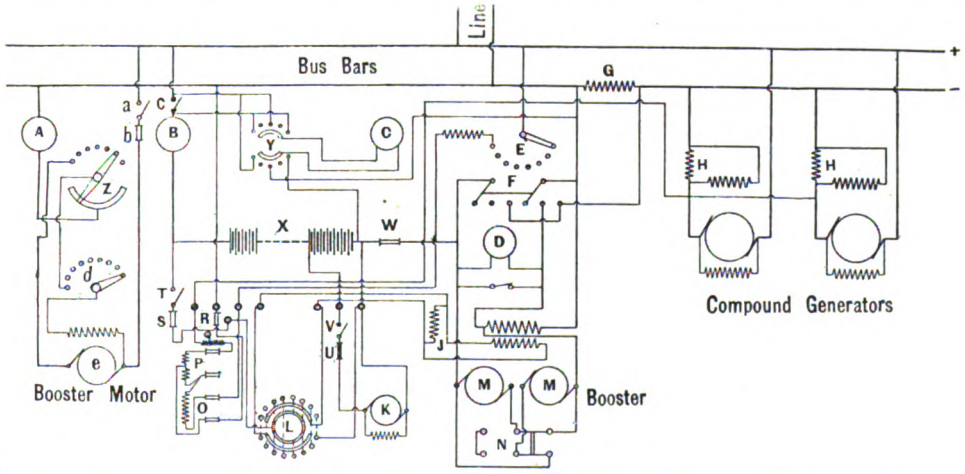

FIG. 35.—TO ILLUSTRATE THE CONNECTIONS FOR THURY BOOSTER, LEICESTER TRACTION STATION.

A. Motor ammeter, having a range of 70–0–140 amperes.
B. Battery ammeter, having a range of 450-0–800 amperes.
C. Voltmeter, having a range of 150–0–600 volts.
D. Booster voltmeter, with a scale reading 75–0–150 volts.
E. Adjustable solenoid resistance, together with a permanent resistance.
F. Double-pole, three-way switch.
G. Series diverter for the booster.
H. Diverter for the compound winding of the main generators.
I. Rotation cut-out.
J. Shunt.
K. Motor for automatic pressure regulator.
L. Automatic pressure regulator.
M. Booster commutators.
N. Double pole charge-over switch.
O. Fixed solenoid of automatic pressure regulator
P. Moving solenoid of automatic pressure regulator.
Q. Permanent resistance in series with the solenoids.
R. Solenoid fuse.
S. Excitation fuse.
T. Excitation switch.
U. Regulator motor fuse.
V. Regulator motor switch.
W. Battery fuse.
X. Battery.
Y. Three-way voltmeter switch.
Z. Starter for booster motor.
a. Switch for booster motor.
b. Fuse for booster motor.
c. Battery switch.
d. Shunt regulator for motor.
e. Motor for driving the booster.

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shunt winding of the booster is shown in Fig. 35. The apparatus is based on the principle that with the drop or rise of pressure, resistance is to be cut out or inserted in the excitation circuit of the generator. The controller of the apparatus is a "click" device, operated by means of solenoids. In the case of an abnormal voltage, the click device acts on a toothed wheel, which rotates the switch arm of the shunt regulator backward or forward by means of a small electric motor running at constant speed. When the suspension spring of the click work is exactly balanced by the solenoids on normal pressure, the click escapes from the toothed wheel, leaving the same motionless with the switch. The sensitiveness of the controlling devices can be regulated by means of a screw. To illustrate the sensitiveness of the apparatus, it may be stated that it can complete the full regulation from no-load to full-load in fifteen to twenty seconds, and this speed can be doubled if required.

This construction of automatic pressure regulator embodies many advantages, foremost amongst which may be mentioned :—

1. A very exact regulation is obtained, independently of the mechanical power necessary to move the regulating gear. The power required is very small, the standard size being one-tenth horse-power motor.

2. The switch-arm, controlled by the toothed wheel, always covers the whole contact surface, intermediate positions being impossible.

3. The controlling arrangement is based on the action of a solenoid, which is the most simple device, acting quickly, and with perfect ease.

4. The regulator permits the voltage to be kept constant within limits of a half of one per cent. of the mean value.

Returning to the booster itself, we see from Fig. 35 that a double-wound armature is employed, and that each winding is connected to its own commutator. The commutators are fixed at each end of the armature core, and by means of a double pole change-over switch the two windings may be connected in series or in parallel, the former arrangement being for charging, and the latter for discharging the battery. The current density in the armature windings is about 2,600 amperes per square inch.

The automatic operation of the booster is as follows :—If the external load be less than the normal, the excess power of the main generators is utilised for the battery charge. For this purpose the differentially excited booster adds its voltage to that of the dynamo, and so allows a charging current to pass into the battery. If the external load is equal to the normal output of the main generators, the excitation due to the differential winding is nothing, and there is neither charge nor discharge. When the external load rises above the normal output of the main generators, the extra current passes through the series winding, overpowering the shunt, and the booster adds its voltage to that of the battery, and so the latter discharges. The three-way switch F (Fig. 35) will permit the following operations. In one position it allows the series winding to be used ; in the second position it short-circuits the series compound winding ; and in the third position it short-circuits the booster entirely. In short-circuiting the series winding, neither the output nor the

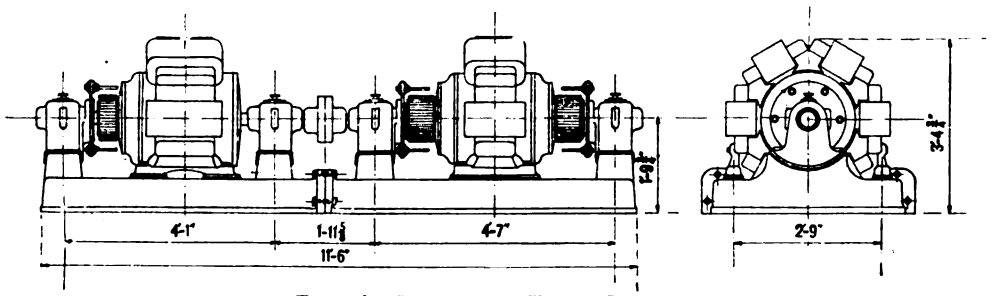

FIG. 36.—DIAGRAM OF THURY BOOSTER.

speed will be varied ; the only object of the compound winding is to compensate for the small space of time allowed for regulating, when the variations of the load on the line are extremely sudden.

The booster in the Leicester traction station is designed for a current of 250 amperes at 130 volts when charging, and 600 amperes at 70 volts when discharging. The efficiency of the motor at full load is 89 per cent. ; on discharge duty the booster has an efficiency of 86 per cent., and 86 per

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cent. on charge. The combined efficiency of the set is 81 per cent., and after a six hours' run at full load, the temperature rise does not exceed 70°F. The machine is capable of dealing with a 25 per cent. overload at any pressure between 20 and 70 volts, and delivers the above-mentioned currents at any pressure between zero and the maximum. The normal speed of the motor is from 650 to 700 revolutions per minute on a 500-volt circuit. The booster armature has a diameter of 575 millimeters, and net iron length of 22 millimeters. The net weight of the set is about 6700 kilograms.

The illustration at the head of this article shows the arrangement of the set, and in Fig. 36 we give an outline drawing with overall dimensions.

The battery consists of 240 cells of the standard Tudor pattern (type No. 413 H. F. 19). It is capable of giving 270 amperes for three hours, 360 amperes for two hours, 630 amperes for one hour, and 900 amperes for short periods. The cells are contained in lead-lined wood boxes resting on glass oil-insulators; the stands are made entirely of best pitch pine, painted with three coats of acid-proof paint, and no metal fastenings of any sort are used. The stands are supported on large porcelain oil-insulators to ensure perfect insulation of the whole battery from earth—a point of considerable importance with the high voltage in use at the present day, especially as either one pole or the middle wire is usually earthed.

(*To be continued.*)

ALTERNATING AND POLYPHASE CURRENT PROBLEMS.

PART I.—INDUCTANCE.

By ELLIS H. CRAPPER, M.I.E.E.

IN continuous current working the current traversing a circuit is directly proportional to the impressed voltage and inversely proportional to the resistance of the circuit; it follows that the drop in volts which accompanies the continuous transference of a constant quantity of electricity along a conductor is given by the product of the current in amperes and the resistance in ohms. If, however, alternating currents are employed, the drop in volts is given by this product only when the circuit is non-inductive. In most cases the drop in volts which occurs when an alternating current traverses a circuit is *greater* than when a constant current of equal strength traverses the same circuit, and the circuit is then said to be *inductive* and to possess *inductance*, as well as resistance. *Inductance* may be defined *as that property of a circuit by virtue of which an E.M.F. of self-induction is set up in the circuit when the current traversing it is changing in magnitude; this induced E.M.F. reacts on the current tending to oppose the change in the strength of the current.* When alternating currents of a definite frequency traverse such circuits only part of the impressed pressure is utilised to overcome the resistance of the circuit, the remaining portion being required to neutralise the E.M.F. of self-induction set up; the impressed E.M.F., in fact, is split up into two components corresponding to the parts mentioned, termed respectively the *power E.M.F.* and the *reactive E.M.F.* From first principles it is obvious that the magnetic flux linked with the conductors forming the circuit will be of the same character as the current, hence the inductive action, according to the principles of electro-magnetic induction, results in the reactive component being in quadrature, *i.e.*, has a phase relationship of 90° with the power component, the one being a maximum when the other is zero. The actual effect of inductance is twofold: (1) it increases the obstruction offered to the passage of electricity, and (2) it gives rise to a phase displacement between the current and the impressed E.M.F.

The practical unit of inductance is the *henry*, and its symbol is L. *The henry is defined as that inductance which gives rise to an E.M.F. of self-induction of one volt when the time rate of change in the current*

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is one ampere per second, and algebraically we have

$$E_s = L \frac{\delta i}{\delta t}$$

where E_s is the E.M.F. of self-induction; and in alternating current working, when the virtual value of the current is I amperes, and the frequency is f periods per second

$$E_s = 2\pi f L I \text{ volts.}$$

These remarks refer to the elementary principles of alternating current working which are fully dealt with in most text-books on alternating currents, and are only included in these notes so as to form an introduction to the determination of the inductance of a single-phase transmission line of considerable length.

PROBLEM 1. *Determine the inductance of a loop formed by two indefinitely long parallel line wires, each of radius r cms., fixed at an interaxial distance d cms. apart in a medium of unit permeability.*

All single-phase overhead transmission circuits comprise two wires separated by a distance (which is great enough to avoid contact due to sag or movement, and to ensure the required degree of insulation); they form a loop and enclose such an area that the flux linked with the conductors may be considerable, and, since it is alternating in character,

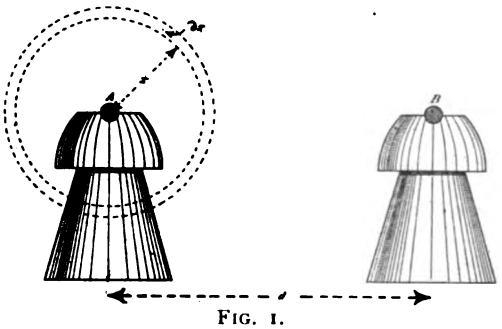

FIG. 1.

it gives rise to a correspondingly large inductive drop. Let A and B (Fig. 1) represent the two wires. The inductance of such a system is, by definition, given by the E.M.F. of self-induction set up by unit rate of change in the current, and the inductance L of a given length l cms. in either wire will be constant so long as the permeability of the medium is constant, since the variation in the induction only depends upon the time rate of change of the current; thus to calculate L it is only necessary to determine the total flux in the loop linked with a current whose time rate of change is unity. Let us consider the wire A. The flux linked with A is partly external to the wire, and partly within its substance, consequently the flux may be split up into two portions, *i.e.* (1) the external flux, and (2) the internal flux, and it tends to simplification to deal with each separately in the determination of L.

Dealing with the external portion first, and using c.g.s. units, we have as the measure of the intensity of the magnetic field (lines per sq. cm.) at any point P, due to a constant current I traversing the wire A, the

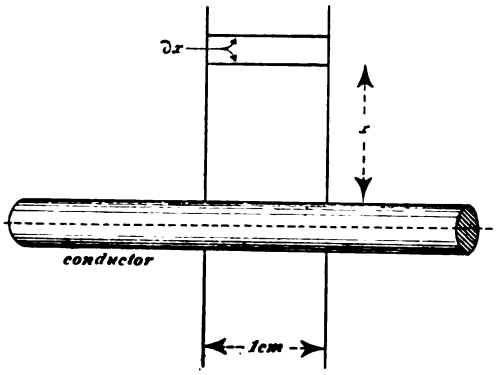

FIG. 2.

ratio of the magneto-motive force to the reluctance of the path of the flux, or

$$H_p = \frac{4\pi I}{2\pi x} = 2\frac{I}{x}$$

where x, which is greater than r, is the radial distance O P from the centre of the wire A. Now to obtain the time-rate of change in the flux, linked with each centimeter of the conductor when an alternating current is used, let us consider the flux between the two vertical planes, one centimeter apart, as shown in Fig. 2. And since $H_p = 2\frac{I}{x}$, the flux δN over the area $1 \times \delta x$, concentric with the conductor, will be

$$\delta N = \frac{2I}{x} . \delta x$$

and the total flux N, threading the loop from the surface of A to the centre of B, so far as it depends upon A's current, is the integral of the above expression between the limits $x = r$ and $x = d - r$, therefore

$$N = 2I \int_r^{d-r} \frac{\delta x}{x}$$
$$= 2I \log_e \left(\frac{d-r}{r} \right)$$
$$= 2I \log_e \frac{d}{r},$$

since r is small compared with d.

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This is the flux which encircles, and is linked with each centimeter of the conductor, and the time-rate of change in the linkages due to a flux changing with the current gives the magnitude of the E.M.F. of self-induction set up, therefore

$$\frac{\delta N}{\delta t} = 2\left(\log_e \frac{d}{r}\right)\frac{\delta i}{\delta t}$$

but

$$E_s = \frac{\delta N}{\delta t}$$

$$= L_1 \cdot \frac{\delta i}{\delta t} \text{ (by definition)};$$

consequently $L_1 = 2 \log_e \frac{d}{r}$,

where L_1 is the inductance per centimeter due to the external flux.

As regards the flux within the conductor, it must be noted that the density of the flux decreases from a maximum value at the surface to zero at the axis; at the same time we may assume a uniform distribution of current over the section of the conductor, so that within the substance of A, at a radius x_1, the flux density for that cylindrical surface will be

$$B = \frac{2I}{x_1} \times \frac{\pi x_1^2}{\pi r^2} = \frac{2 I x_1}{r^2},$$

and the penetrating flux for a breadth δx per centimeter is

$$\delta N_1 = \frac{2 I x_1}{r^2} \cdot \delta x_1$$

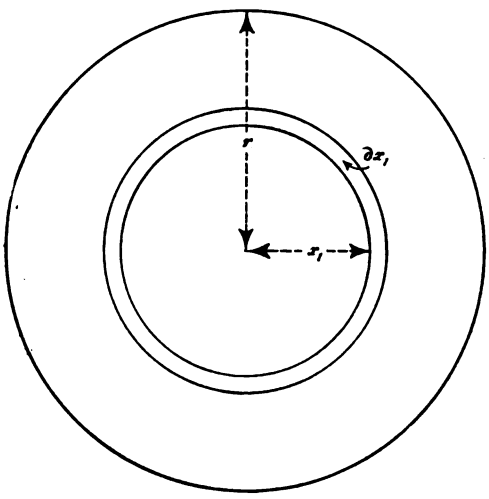

FIG. 3.

But this flux is not linked with all the current, but with that portion only which is within a cylinder of radius x_1, *i.e.*, with $\frac{x_1^2}{r^2}$ths of the wire, so that the current flux linkage for the element δx_1 (Fig. 3) is

$$\delta N_1 = \frac{2I}{r^4} x^3 \cdot \delta x.$$

The total flux linkage within the wire will be the integration of this expression between the limits $x = 0$, and $x = r$, therefore

$$N = 2I \int_0^r \frac{x^3}{r^4} \cdot \delta x$$

$$= \frac{I}{2}$$

and L_2 for unit rate of change of current will be

$$L_2 = \frac{I}{2}.$$

The inductance L per centimeter is, in absolute units, the sum of the two components L_1 and L_2, or

$$L = L_1 + L_2$$

$$= 2\left(\log_e \frac{d}{r}\right) + \frac{I}{2},$$

and for a length l centimeters

$$L = l\left\{\frac{I}{2} + 2 \log_e \frac{d}{r}\right\}$$

therefore for the complete loop or circuit

$$L = 2l\left\{\frac{I}{2} + 2 \log_e \frac{d}{r}\right\}$$

To reduce to practical units and lengths of transmission circuit in feet, proceed as follows:—

$$L = 2l^1 (2{\cdot}54 \times 12) \times \left\{0{\cdot}5 + 2 \times 2{\cdot}3026 \log \frac{d}{r}\right\} 10^{-9} \text{ henry}$$

$$= 2l^1 \left\{15{\cdot}24 + 140{\cdot}366 \log \frac{d}{r}\right\} 10^{-9} \text{ henry}$$

$$= 2l^1 \times 140{\cdot}36 \left\{{\cdot}10857 + \log \frac{d}{r}\right\} 10^{-9} \text{ henry}$$

$$= 2807\, l^1 \left\{{\cdot}10857 + \log \frac{d}{r}\right\} 10^{-10} \text{ henry}.$$

(To be continued.)

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SPECIAL DEVICES USED IN WEAVING.

PART VII.—SOLID OR TUBULAR PIRN-COP WINDING MACHINES.

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By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

SOLID or tubular pirn-cop winding machines constitute another variety of a distinctly different type from any that have been previously described in this series of articles, and one that occupies an important position in the particular field of manufacture to which it belongs. Machines of this type are chiefly designed for winding comparatively coarse and strong weft used in the production of fabrics of heavy textures of worsted, linen, jute and cotton, such as carpets, rugs, mats, heavy tapestries, furniture upholsterings, and counterpanes. Weft employed for these and similar fabrics is sometimes of such a character, as regards strength, bulk, and other qualities, as to require a different mode of building up the yarn from that which obtains in ordinary pirn winding, which latter is better adapted for finer and weaker material.

Before proceeding to describe the construction and operation of solid cop pirn winding machines, it will be helpful to a clearer comprehension of their true function to briefly review the general features of ordinary pirn winding and of tubular cop winding, with a view to indicating their chief points of difference. In ordinary pirn winding, threads are wound upon *wooden pirn bobbins* or paper tubes in a series of successive layers of comparatively *finely-pitched* coils, by imparting to them a *slow* reciprocal traverse as they pass on to their respective bobbins, that are *rotated frictionally*, and therefore negatively, either indirectly by means of spindles and wharves driven by bands from a tin drum, or else directly by their surface contact with friction discs or cones. The finer and weaker yarns require the more gentle action of a slow traverse, and as that causes yarn to wind with a close spirality, it is necessary to place it upon a bobbin or tube to form a core and give it sufficient support to enable it to be handled and woven with safety.

In tubular pirn-cop winding, however, bobbins or tubes may be entirely dispensed with by winding threads direct on to *bare spindles*, on which they are placed in a series of successive layers of *coarsely-pitched* coils. This is accomplished by imparting to the threads a *quick* reciprocal traverse as they pass on to their respective spindles, which are generally *rotated positively* by means of wheel gearing. Spindles are also driven independently; and, in the best machines, they are each provided with an automatic stop-motion to cause them to stop independently both when their respective threads either break or run out, and also when their cops have attained a pre-arranged length.

Solid or tubular cops are constructed in two slightly dissimilar styles, as illustrated in Figs. 43 and 45. Those represented in Fig. 43 require the use of shuttles specially adapted to receive them, and, during weaving, a thread is withdrawn from the basal end of a cop, as indicated by the arrow-head. One of these specially-adapted shuttles is illustrated in Fig. 44. Unlike an ordinary shuttle, it is without a tongue or skewer, and is open only at the top. Its interior is deeply and sharply serrated, with the ridges and furrows formed transversely to the length of the shuttle, and resembling a saw-tooth roof. When a cop is forced into a shuttle, the ridges become embedded into its side, and hold it firmly in position. This is assisted by forming the serrations with the longer sides facing the *shuttle eye and base of the cop* (whence the yarn is withdrawn), and with the shorter and steep sides facing the *cop nose*. After a cop is pressed into position it is closed in either by means of an elastic band, or else a thin steel cover, with the object of checking any tendency which it may have to rise in a shuttle, due to the frequent concussion of the latter against the shuttle-box, and thereby prevent it from catching against the upper line of warp-ends, and breaking them, as it passes through the warp shed.

Since a thread is withdrawn from the interior and hollow basal end of a cop, it tends to leave the latter in loops or rings that are liable to pass into cloth, and may also

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FIG. 43.
TUBULAR PIRN COP.

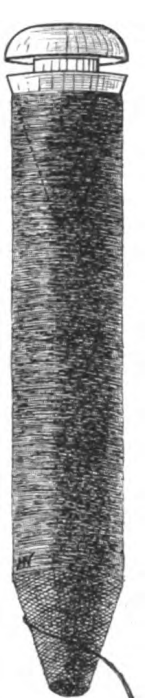

FIG. 45.
HALF-PIRN TUBULAR COP.

prove troublesome during weaving. Also, in consequence of yarn being unsupported at the extreme base of a cop, it is liable to collapse at that part, and cause considerable waste, especially when the cop is nearly exhausted. In order to avoid those disadvantages, some manufacturers prefer to build up the cops into what are termed "half-pirns," as represented in Fig. 45. These have their initial or basal extremity wound upon a pirn bobbin head to provide a support for yarn at that part, and thereby prevent its collapse and consequent waste. When formed into half-pirns, the cops are fixed upon the tongue or skewer of an ordinary shuttle, and have their threads withdrawn from the exterior and nose of a cop, as indicated by the arrow-head. This circumstance gives rise to what is regarded by some to be a disadvantage that does not exist when a thread is withdrawn from the interior of an unskewered cop. Thus, as a thread is withdrawn from the nose of a cop contained upon a skewer, it becomes coiled around the latter in a spiral formation which increases its number of coils as a cop diminishes in length. This causes a gradual increase of frictional resistance to the withdrawal of a thread, with a corresponding increase of tensile strain upon it, and its consequent stronger inward pull upon selvedge warp-ends during weaving. It also increases the tendency to divert a shuttle from its proper course in its passage through the warp shed.

Tubular pirn-cop winding machines are constructed by different makers in a great variety of forms, for each of which is claimed by them some special merit or suitability for specific purposes; but they all possess many features in common, and differ chiefly in minor details of construction. Some are of stronger build and better adapted for winding stronger and coarser material, and for producing larger cops; whilst others are more suitable for lighter and finer yarn. Frictional or negative driving of spindles has been tried in these machines, but that course has not been successful, especially for the heavier grades of yarn. The failure of frictional driving is due to the enormous power required to overcome the considerable degree of tension it is necessary to impart to the threads in order to produce a hard, firm, and compact cop of large dimensions, and one containing a great length of yarn. When spindles are frictionally driven, the tension due to the resistance of yarn, during winding, tends to retard their velocity, thereby curtailing production, and causing inferior work. The building up of yarn, in machines of this class, is sometimes effected by means of metal pirn cups (with all their attendant evils of flattening, glazing, and abrasion of yarn), and sometimes by means of conical bowls or rollers, as in other pirn winding machines.

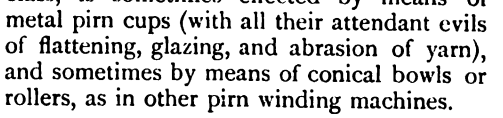

FIG. 44.—TONGUELESS SHUTTLE FOR TUBULAR OR SOLID PIRN COPS.

One of several modifications of a tubular pirn-cop winding machine, known as Grayson's, is illustrated by a sectional elevation in Fig. 46, which shows a complete set of parts for only one spindle on one side of the machine. The machine may be made with either a single row of spindles (as shown) or with two rows, with the several parts for each row placed symmetrically on each side of a central line, to constitute a duplex machine, or two complete sets of parts placed back to back. As represented in Fig. 46, the

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machine contains a driving shaft A extending its full length, and carrying a number of skew-geared wheels B fixed at regular intervals corresponding with those at which spindles I are placed. Spindles I are placed with their axes in a vertical plane situated about 1¼ in. to the rear of shaft A. Each spindle passes freely through a round axial hole formed in a small bevel wheel C, having an extended boss to form a lug D; hence, wheel C may freely revolve upon its spindle without rotating it. Immediately above wheel C, the spindle also passes freely through a hole formed in a jaw clutch E, which hole is oblong in shape, and exactly counter to the transverse section of a spindle (as represented in Fig. 47), so that a clutch may slide freely along its spindle but cannot revolve without turning the latter. The clutch is also formed with an annular groove or neck spanned by a fork F, that is secured by a swivel attachment to a long unevenly-balanced lever G, fulcrumed at H, so that its heavy end (shaded) always tends to fall by gravitation, in which event the clutch is raised, and becomes disengaged from its small bevel wheel. Therefore, so long as the clutch is held out of gear with wheel C, the spindle will remain stationary, and may only be set in motion by depressing lever G, so as to connect the clutch and wheel, as represented in the diagram. The upper portion of a spindle (which revolves within a metal pirn cup J) gradually tapers for about 18 inches towards the tip, which is formed with a left-hand thread upon

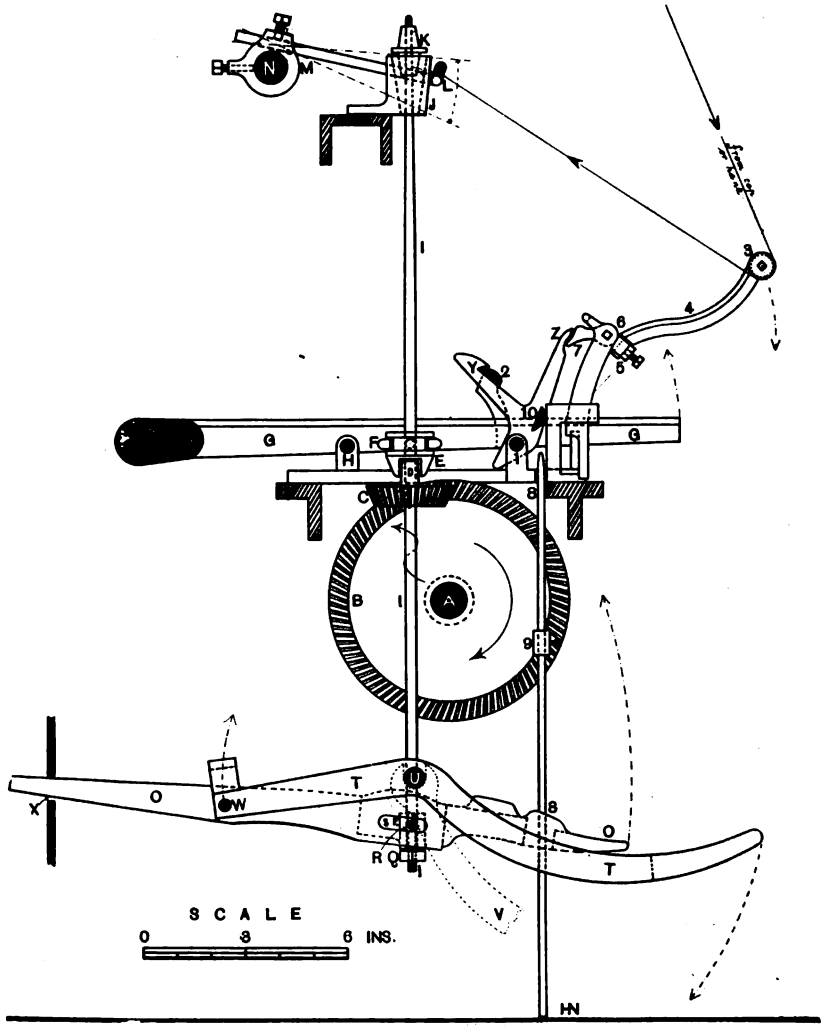

FIG. 46.—GRAYSON'S SOLID OR TUBULAR PIRN-COP WINDING MACHINE.

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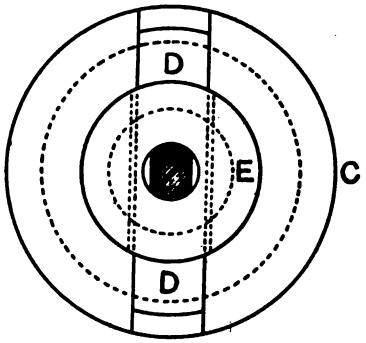

FIG. 47.—SECTION OF SPINDLE, AND PLAN OF CLUTCH AND BEVEL WHEEL.

which a brass screw-cap K may be screwed on as the spindle revolves. The screw-cap serves to prevent a cop slipping off its spindle, and the left-hand thread opposes any tendency of the cap to unscrew and come off, during winding. As threads pass on to their respective spindles, they are guided within the pirn cups by means of guiders L, fixed in brackets M, secured to shaft N, to which a very rapid oscillatory motion is imparted by means of an eccentric, a crank, or cam, so as to place the threads in coarsely-pitched coils to produce firmly-bound and compact cops. The lower extremity of a spindle is connected to a treadle lever O by means of a square loose bush P, in which the spindle foot revolves, and from which its withdrawal is prevented by means of a nut Q screwed on the spindle end. Bush P fits loosely in a recessed or hollowed part of lever O, and is cast with two short studs R, one on each side, that enter side slots S in the lever. Treadle lever O operates in conjunction with another treadle lever T, which is cast hollow, so as to receive between its sides about two-thirds of the forward portion of lever O. Treadle lever T is cast with two studs U that are fulcrumed upon brackets V (shown in dotted lines, and broken short), which support the treadle; and the two treadles are connected by passing a pin W through both. It will now be readily seen that, as a spindle rises, it will raise lever O, whose rear extremity enters a vertical slot X, in the cast-iron plates extending centrally from end to end of the machine. As treadle O rises, it bears against the upper end of the slot, which serves as a fulcrum for it. At the same time, the rear end of treadle T is raised by means of pin W, thereby causing the front of the treadle T to fall, all of which movements are indicated by dotted arrows. The functions of the two treadle levers will now be easily understood. By depressing treadle T, a spindle will rise and lift its cop out of a pirn cup to enable an operative to recover one end of a broken thread for piecing; and by depressing treadle O, after removing screw-cap K, a spindle will be forcibly withdrawn from its cop for removal.

It now remains to describe what constitutes the most interesting and ingenious feature of this machine—namely, the means by which a spindle is caused to cease rotating in the event of the supply of yarn to it failing from any cause, and also when a cop has attained to any pre-arranged length. The automatic stopping mechanism is designed to act upon clutch E, so as to retain it in gear with the lug of bevel wheel C, and cause a spindle to rotate until either yarn fails in its supply, or until a cop is finished, when the clutch becomes automatically released from the wheel, and the spindle stops, thereby requiring the stop-motion to be actuated from two independent sources. The retention of a clutch in gear with wheel C is effected by means of a hook Y, taking over a projectior of a bracket Q, secured to weighted lever G. The hook Y is formed at the end of one of two arms of an L-lever Y, Z, fulcrumed at 1. By forcing the retaining hook Y off the projection of bracket 2, lever G is released, and the weighted end falls by gravitation, thereby disconnecting the clutch from the wheel, and stopping the spindle

During winding, as each thread proceeds from its source of supply to a spindle, it passes underneath a porcelain runner 3, carried on the free end of a short arm 4. This arm is secured to holder 5, swivelled on a pin 6, supported by a bracket. The arm-holder is cast with a short arm 7, so that i may act upon arm Z of L-lever Y, Z. So long as arm 4 is held up by the tension of a thread, as indicated, hook Y retains its hold of bracket 2, and keeps the clutch in action; but if, from any cause, arm 4 is allowed to fall, as indicated by a dotted arrow, arm 7 bears against arm Z, thereby forcing hook Y backward, whereby lever G is enabled to rise and withdraw its clutch out of gear with its driving wheel to stop the spindle.

The stoppage of a spindle due to the completion of a cop is effected in the following manner: A long vertical rod, 8, passes through a hole near the front of treadle-lever O, and rests, normally, upon the floor. Its upper extremity, which is slightly tapered, points immediately underneath a half-moon projection, 10, cast upon L-lever Y, Z, which

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projection bears lightly against a part of the machine framing. Rod 8 carries an adjustable hoop or collar, 9, that may be set-screwed on any part of its length according to the length of cop required. As a spindle ascends, it raises treadle-lever O, which eventually comes in contact with hoop 9, thereby raising rod 8, and forcing it between the framing and projection 10. By this means, L-lever Y, Z is pushed backward to release lever G, which rises and disconnects the clutch from the lug of its driving-wheel, thereby causing a spindle to stop, in the manner just described.

(To be continued.)

THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C., Chemical Engineer and Consulting Chemist, Manchester.

The Air-Bath and its Technical Equivalents.

THE air-bath is used in the laboratory for drying substances at definite temperatures. It may be heated directly by gas, or the heat may be transferred to its interior through a water jacket. The purpose of the drying operation is, in most cases, to expel water or other liquids from finely divided solids, but cases occur in which one liquid has to be separated in this manner from others which boil at higher temperatures. As the problem of expelling superfluous water from solids is the one which most frequently occurs in practice, we shall confine our remarks to this particular case.

It must be clearly understood that the operation of drying is not identical with that of ordinary evaporation. In ordinary evaporation, by the application of heat and by the evolution of steam, we produce currents which cause the particles of the liquid to move about freely, and thus to carry the heat away fairly well. Thus, although water and many compounds which dissolve in it are in themselves exceedingly bad conductors of heat, yet in the process of evaporation the bad conductivity is overcome by the mobility of the liquids. But whenever the problem before us consists in drying a wet mixture in which the solid particles cannot move freely, we have to take into consideration, and allow for the fact, that the heat has to be transferred through a bad conductor. We know that, under ordinary conditions, one pound of coal will evaporate from five to ten pounds of water; but it is impossible, with an equal expenditure of heat, to expel anything like this quantity of water from a pasty mass, and the best mechanical arrangements will not enable us to obtain results which, in ordinary evaporation, would be considered barely satisfactory.

In the laboratory, we may use the air-bath either with an opening at the top, through which the vapours evolved may pass; or we may have an opening at the bottom as well, and thus produce a current of air during the drying process. If we adopt the latter arrangement, we shall find that we obtain the desired results in a shorter time; the moist substance, instead of being in a stagnant atmosphere saturated with moisture, is exposed to a constant current of air which, not being fully saturated with water, will take up moisture in its passage. The same principle applies to work on a large scale; but whilst the small quantities manipulated in the laboratory are generally left undisturbed in the air-bath, the large quantities dealt with on a manufacturing scale have to be stirred up by hand, or by mechanical means, or they may have to be moved about and transported from one part of the drying machine to another.

In dealing with substances which have to be thoroughly dried, it is necessary in the first instance to deprive them of as much moisture as possible, by the means explained in former chapters. Crystals should be drained, and where possible dried, by a centrifugal machine; precipitates should be deprived of as much water as possible by means of filter-presses or other pressing machinery. Only after such preliminary

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treatment has been carried out, should the process of drying by heat be resorted to.

As it is often necessary to make use of mechanical arrangements which recur in different types of drying apparatus, it may be advisable to give a description of an appliance which we have so far had no occasion to consider; a study of this will render the subsequent explanations of drying machinery more lucid and easier to understand.

Suppose we have many tons of crystals which have to be transported from one end of a room to the other; we could do this by transporting them in a wheelbarrow or wheelbarrows, but the same object could be attained by having a roller fixed at either end of the room, over which a sheet of calico of the width of the rollers is stretched in such a manner that it becomes an endless belt. On turning the rollers the endless belt would move at a speed which could be modified by adjusting the speed of the rollers, and any substance placed upon the top part of the endless belt would travel from one end and be discharged at the other end of the room. Instead of a belt made of calico, we could use an arrangement made in metal, consisting of thin metal laths, wire netting, etc. Such an arrangement is largely used for transporting goods in works, and is known as a *carrier conveyor*. One of these is shown in Fig. 27.

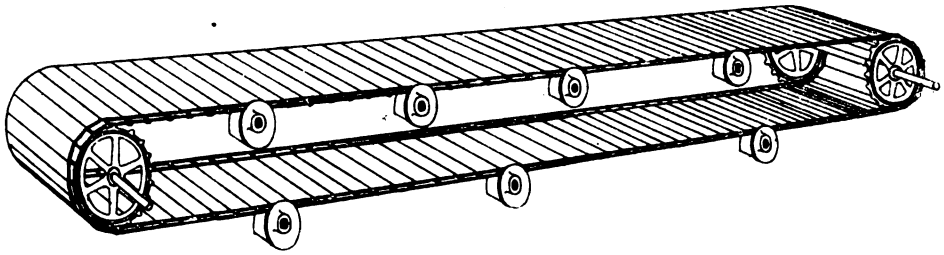

FIG. 27.—CARRIER CONVEYOR.

Another way of obtaining the same result would be to place a long Archimedean screw in a trough; on turning the screw, any substances placed in the trough would be moved in the direction of the axis of the screw. Such an arrangement is known as a *screw conveyor*, and is shown in Fig. 28. It works remarkably well with dry, or comparatively dry substances, but is not so efficient in the case of pasty masses, which are apt to stick. In such contingencies, an arrangement may be used in which an endless chain travels over sprocket wheels. Bars, which act as scrapers, are fixed to the chain at convenient intervals; as the chain revolves, these take up and carry forward any substances which they meet. An arrangement of this kind is called a *drag plate conveyor*, and is represented by Fig. 29. The arrangements which we have so far discussed enable us to transport goods in a horizontal or slightly inclined direction. If it is desirable to transport goods in a vertical direction, or at a considerable angle to the horizon, we may make use of an endless chain, to which buckets are attached at convenient intervals. These buckets dip, at the lowest point, into the mass which has to be transported, and so

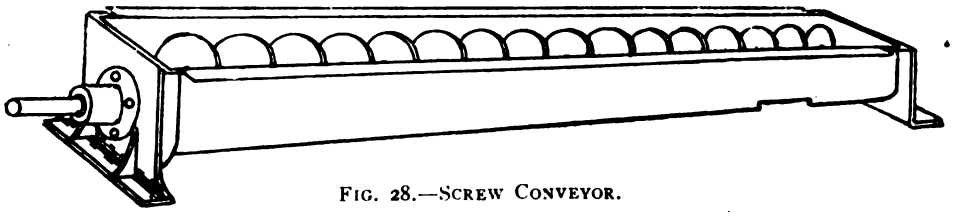

FIG. 28.—SCREW CONVEYOR.

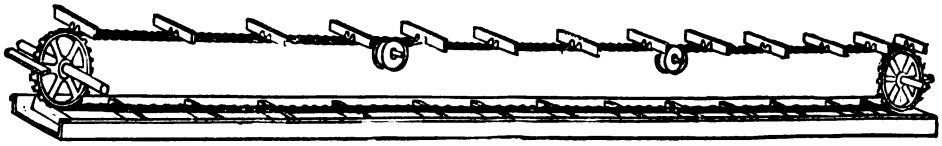

FIG. 29.—DRAG PLATE CONVEYOR.

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become filled. After travelling upwards they will, on passing the highest point, gradually turn over and discharge the mass which they contain. Such an arrangement goes by the name of the *bucket elevator*, and is shown in Fig. 30. All these arrangements are largely made use of in the construction of drying plants, and we may now proceed to describe some systems in detail.

The nearest approach to the air-bath, as used in the laboratory, would be a chamber through which hot air is made to circulate; this may be built of wood, brick, or other suitable material, and well protected against radiation. Such an arrangement is frequently used, and various details of construction are applied to it. The heating may take place inside the chamber, by means of steam pipes; or the air may be heated before it enters the chamber; or a mixture of air and the products of combustion from a coke fire may be passed through the drying chamber, in cases where the presence of carbonic acid would not be injurious. Again, air may be either drawn through the system, or it may be forced into it. The latter arrangement is the better of the two, as it prevents cold air from being drawn into the apparatus if there should be any leakage. A number of such chambers may be placed one on top of another, forming a high building; each storey may be heated separately, or may receive its heat from the storey below it. The substances to be dried may be placed on racks or trays which are fixtures in the drying chambers, or a number of trays may be built up one above another into a set of shelves, and placed on bogies, so that they may be easily wheeled into or out of the drying chambers for the purpose of filling and emptying. It is difficult, in these arrangements, to obtain an even distribution of heat; hence the substances in different parts of the system do not generally finish drying in the same time.

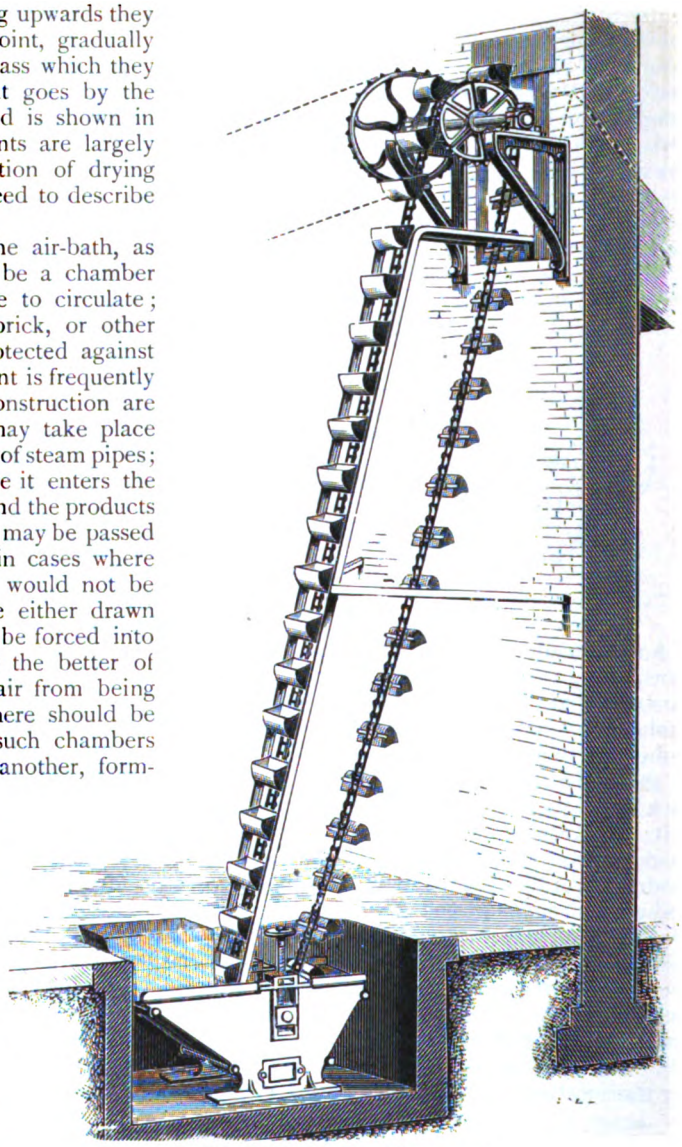

FIG. 30.—BUCKET ELEVATOR.

The simplest form of drying apparatus would appear to be one which consists of a long plate or a shallow pan, heated by means of an ordinary fire in such a manner that the flue gases pass along channels underneath the plate or pan. Various metals, enamelled iron, or earthenware tiles could be used for constructing the drying bed. The heat of the bed would be greatest near the fireplace, and least at the end farthest from it; thus the material to be dried might be introduced at the cold end and moved gradually by rakes towards the hot end. In such an arrangement, however, it would be impossible to keep the temperature within a narrow range, and it would be quite impracticable in the case of compounds which decompose above 100° C. or thereabouts. In such a case, a steam-jacketed shallow pan might be used, care being taken to make the flat bed of sufficiently strong material to stand the pressure of the steam without

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bulging. An arrangement might be used in which the heat is transmitted to the bottom of the tray by means of steam pipes: the writer has found that the efficiency of this construction can be increased by embedding the steam pipes in dry iron filings, and placing the bed upon the top layer; as the iron filings conduct heat well, this is a fairly economical way of transmitting the heat of the steam. We may mention that a similar design also furnishes an excellent sand-bath in laboratories where steam is available. Steam coils are placed in a square box of about four inches deep, made of wood or sheet iron; the box is filled up within half an inch above the coils with dry iron filings, and a layer of one inch of sand is placed on the top of this.

According to the pressure and temperature of the steam, which can be regulated by means of a reducing valve, the sand-bath may be kept at a uniform temperature of 100° C. to 120° C.; with superheated steam, a temperature up to 300° C. or more may be obtained. Instead of steam pipes or steam coils, advantage could be taken of the arrangement which we have shown in Fig. 12 (TECHNICS, Vol. III., No. 13, January, 1905, p. 49), in which wrought iron pipes are cast into iron plates.

In the arrangements which we have described, the air has free access to the substances to be dried. In some cases it may be desirable to carry on the drying in a closed system; this could easily be effected by providing any of the before-mentioned arrangements with a lid, and carrying off the vapours by means of a mechanical arrangement such as a pump, a fan, or an injector.

From the remarks which we have made at the beginning of this article it will appear that in many cases the drying operation will not proceed on economical lines unless the mass is frequently agitated and turned over. In other cases the substances have to be gradually moved from the coldest to the hottest part of the system. This, if done by hand, requires constant attention and labour, and therefore involves extra cost; wherever it is practicable, mechanical appliances are, therefore, employed. There are many ways in which the work involved in turning over substances whilst drying can be effected by machinery. One of the simplest would be to have a shallow trough at the bottom of which works an endless screw, such as we have previously described. This trough could be heated in either of the ways which we have mentioned, and the speed of the screw could be so arranged that the substances are carried from end to end in the time required to reduce them from the wet to the dry state. Instead of spiral conveyors, dragplates could be made to move on a flat plate, and thus to carry the substance forward; but in this case the amount of stirring would be inconsiderable, and pasty substances would be liable to be carried along in almost solid blocks.

Efficient drying arrangements have been constructed in the form of long cylinders, in which the substances to be dried are gradually and slowly moved from end to end by means of large screws; at the same time little buckets fixed on the revolving axle lift the stuff from the bottom, and, after carrying it round, drop it again, and thus produce a thorough mixing and separating. It is evident that here again many ways of heating the apparatus may be used. Thus in one arrangement the coal or coke fire is made to heat the air which is passed through the drum, whilst the products of combustion are taken round the drum, thus heating it from the outside; or the drum may be double-cased and heated by steam, and so on. In another type of drying machinery, a long chamber, provided with doors at opposite ends, may be heated by any means described above. The substances to be dried are placed in little waggons which run along the chamber on a tramway; these waggons are introduced into the chamber by means of long rods, and left in it for the necessary time. Where space has to be economised, the chamber may be built vertically; in that case the little waggons are raised or lowered by means of chains.

Another arrangement which is largely used consists of a drying chamber in which carrier conveyors are arranged one above another in such a manner that the substances fed in at the top pass along the highest band, and are made to drop on the band below, which projects at that end and moves in an opposite direction; and so on from the higher to the lower, until the substances are discharged at the bottom of the apparatus.

In drying installations, the use of machinery to economise hand labour is not restricted to the drying chamber itself. The wet stuff or finished material can be moved away or towards the place by means of bucket elevators, and the other arrangements mentioned may be used for the same purpose. Economy of labour and economy of heat are the two main principles which underly the construction of such installations. As regards the former, the problem has been solved very

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efficiently; but with regard to the latter, it is still capable of improvement, and even with the most perfect designs it has been so far impossible to effect more than the evaporation of 5 lbs. of water for every pound of coal burnt. It need hardly be mentioned that in all cases where waste steam, or waste heat from other sources is available, this should be used for the purposes of drying.

We shall conclude this article with an interesting illustration of how it is possible to got over difficulties which at one time seemed almost insurmountable. It is now possible to dry explosive substances by heat; this is effected by utilising our knowledge that, with a sufficient vacuum, water will boil and evaporate at a low temperature. The construction which is used consists generally of a closed metal drying chamber heated by steam and supplied with shelves on which the material to be dried is placed. The chamber is connected with a large "explosion" chamber, fitted with a great number of safety valves. If at any time an explosion should occur, the gases evolved would be driven into the explosion chamber, which always is in a state of vacuum, and any surplus pressure would cause the safety valves to be thrown open. When the drying is complete, the steam is turned off and cold water is passed through a system of pipes conveniently arranged in the chamber; by this means the whole system is cooled, and finally the explosive substances can be removed without danger. For obvious reasons all steam and water taps are arranged at a distance from the apparatus, so that they can be regulated without the workmen being compelled to go near the drying chamber whilst it is in actual use.

(*To be continued.*)

SMOKE PREVENTION.

A VERY important contribution to the discussion of the *Smoke Prevention Problem* has been published recently in one of the German technical journals. This is in the form of a Report (by a German engineer named Haier) upon a method of attacking this evil that has been adopted in Hamburg with some degree of success. Our readers are probably aware that it is the custom in those English cities where the smoke question has been taken up by the civic authorities, to appoint inspectors, and to take legal proceedings against those infringing the bye-laws, in the matter of excessive black smoke production. Since the civic action in this matter is spasmodic and irregular, and depends largely upon the presence or absence of manufacturers on the city councils, the results achieved have not been very striking, and the smoke problem in most industrial towns and cities in this country is still unsolved. It is questionable whether more progress would not have been achieved by working along the lines indicated in Herr Haier's report, since it is useless to impose fines for a certain offence, until you have some method of showing the offenders that it is both possible and practicable to avoid it.

The plan described in Herr Haier's report is briefly as follows:—

A society has been formed in Hamburg known as the *Verein für Feuerungs-betrieb und Rauchbekämpfung*, and this society has erected an experimental steam-boiler plant, where trials with different methods of firing, and various patented smoke-prevention appliances, have been carried out. As a result of these trials, the society has proved that the production of black smoke from steam-boiler plants can be greatly reduced without in any degree impairing the evaporative efficiency of the boilers, and it is now proposed to demonstrate with the experimental plant how this reduction of smoke may be attained.

The most important part of the work of the society is, however, that relating to the training of firemen in their duties. A number of specially qualified engineers, with thorough grasp of the scientific principles of combustion, and also of the practical side of steam boiler management, are to be appointed; and these men are to act as temporary instructors and advisers in any works where their services may be demanded.

If necessary, specially trained stokers will also be supplied, to show what can be done with the existing arrangements when under skilled management and control. In this way the ordinary boiler firemen will be technically educated in the proper performance of their duties.

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THE THEORY AND PRACTICE OF STEAM GENERATION.

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PART II.—HEAT PRODUCTION AND TRANSFER.

By JOHN B. C. KERSHAW, F.I.C.

INTRODUCTION.

IN the first article of this series* the writer dealt with the raw materials of steam generation —fuel, water and air—and with the methods to be employed for controlling the supplies of these in a well-managed boiler plant. In the present article the writer will deal in a similar manner with the theory of steam-raising, in so far as this covers the production of heat in the furnace of the boiler, and the transfer of this heat through the plates to the water inside the drum or shell. The conditions governing the effects of scale and grease upon the rate of heat transfer will also be dealt with, and the final section of this article will be devoted to calculations necessary for ascertaining the heat efficiency of the boiler plant, from the results of the chemical tests of the fuel and the flue-gases.

The problem of burning fuel so as to obtain from it the maximum amount of heat, and the transfer of this heat to the water contained in boiler, is not nearly so simple as many engineers have supposed; much of the unsatisfactory practice of the present day must be ascribed to lack of study of the theory of the subject. It is of course impossible within the limits of a magazine article to deal fully with the theories of combustion and of steam generation, but an attempt will be made to draw the reader's attention to those points of especial importance for practical engineers. The author will feel that he has achieved his purpose, if his readers are led to consult some of the more comprehensive and advanced books on the subject. The problems presented by the conversion of the latent energy of coal into the latent energy of steam, are in fact worthy of much greater attention at the hands of engineers and students, than they have yet received.

HEAT PRODUCTION.

All naturally occurring solid fuels contain carbon, oxygen, hydrogen and nitrogen; when these fuels are heated in air, a large number of physical and chemical changes are produced with evolution of heat. The amount of heat produced by the complete combustion of 1 lb. of the elements carbon and hydrogen, in oxygen or in air, is as follows:—

Carbon [amorphous solid] 8,080 lb.-Centigrade units, or 14,544 B. Th. units.

Hydrogen [as gas] 34,500 lb.-Centigrade units, or 62,100 B. Th. units.

In the case of natural solid fuels, however, this heat is not all liberated as such and rendered available for actual work, for the hydrogen is present combined in the solid or liquid state, and a certain amount of heat absorption occurs in connection with the change from this into the gaseous state.

The oxygen and nitrogen are also present in coal in some physical state which has not yet been accurately determined by chemists, and some absorption of heat also accompanies the gasification of these elements.

For practical purposes, however, the production of heat by the combustion of solid fuel may be looked upon as an oxidation phenomenon; the carbon and hydrogen of the fuel being converted into carbon dioxide and water respectively with liberation of heat.

The amount of heat produced by the combustion of 1 lb. of fuel in air varies greatly; it depends upon the chemical constitution of the fuel, and also upon the physical condition in which it may happen to be when it is charged into the furnace. The theoretical heat production is expressed in thermal units, and can be ascertained in two ways, either by calculation from the chemical analysis of the fuel, or by direct determination in one of the various forms of calorimeter. There are two systems of thermal units in current use, one based on the kilogram and the degree Centigrade, and the other upon the pound avoirdupois, and the degree Fahrenite. The latter is known as the British Thermal unit, and represents the amount of heat required to raise one pound of water through 1° F. To convert lb.-Centigrade units into B.Th. units, it is simply necessary to multiply by 1·8, while the corresponding factor for kg.-Centigrade units is 3·97.

As regards calculation of the theoretical heat production, the method of Goutal, based upon the approximate analysis of the fuel, was given in Article I.

Should the figures for the elementary

* See TECHNICS for April, 1905.

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analysis be available, the heat value of the fuel is calculated by the formula of Dulong, or by one of the more recently published modifications of it.

Dulong's original formula was :—

$$X = 8{,}080\ C + 34{,}500\ (H - \tfrac{O}{8}). \quad (1)$$

$$\text{or } X = 14{,}544\ C + 62{,}100\ (H - \tfrac{O}{8}). \quad (2)$$

The first formula gives the result in lb.-Centigrade units, and the second in Fahrenite units (or B. Th. units).

In these formulæ X = the heat of combustion, while C = the percentage of carbon, H = the percentage of hydrogen, and O = the percentage of oxygen in the original fuel. Since it is assumed that the oxygen and a portion of the hydrogen in the fuel are already present in combined form, as water, a proportion of the hydrogen equivalent to the oxygen is deducted from the total, before multiplying by the factors 34,500, or 62,100.

The Dulong formula and its later modifications yield results that in many cases closely agree with the observed calorific values as determined by the more trustworthy types of calorimeter; but in some cases wide discrepancies are found between the two results. These are attributed to the differences in the constitution of fuels, and to the presence of certain hydro-carbon compounds in bituminous fuels. As a general rule, the discrepancy between the calculated and observed results increases with the percentage of volatile matter.

For anthracite, coke, and steam coals, the Dulong formula yields fairly trustworthy results. For fuels containing between 20 and 35 per cent. volatile matter, the Goutal formula is more trustworthy. For fuels containing over 35 per cent. of volatile matter, such as cannel coal and peat, only direct calorimetric determinations will yield results of any value.

In order to express the theoretic heat value of the fuel on a more practical basis, it is customary to state how many pounds of water could be evaporated per lb. of fuel if the whole of the heat energy were to be utilised in the boiler, it being assumed that the water is initially at 212° F., and is simply converted into steam at the same temperature.

The heat absorbed per lb. of steam produced, is then represented by the latent heat of steam, and is 537 Centigrade units, or 965·7 Fahrenite units.

One therefore obtains the lbs. of water which could be theoretically evaporated per lb. of fuel burnt, by dividing the heat value of the fuel (as found either by calculation or by direct observation) by one or other of these figures, according as the result has been expressed in Centigrade or Fahrenite units.

For a fuel with a thermal value of 8,200 Centigrade units, or 14,760 B. Th. units, the evaporative power is therefore $\frac{8200}{537} = 15{\cdot}2$ lbs. This, of course, is an unusually high figure; the evaporative power of an average fuel does not rise much above 14·1 lbs. Since the average evaporation of most boilers is little over 7 lbs. of water per lb. of fuel burnt, the evaporative efficiency of the modern boiler-plant is only about 50 per cent., and there is wide margin for improvement both in efficiency and economy.

The *temperature* which is attained by the combustion of solid fuel in air depends upon three factors: first, the calorific value of the fuel, second, the weight of air used per lb. of combustible, and third, the initial temperature of the air used for supporting combustion. The furnace temperature can be ascertained either by direct observation, or by calculation. For direct observation of furnace temperatures, the method first introduced by Segar, of using cones of different melting points, is the most satisfactory; none of the more elaborate optical or electrical methods are to be trusted at very high temperatures, unless the apparatus be constantly checked by comparison with a standard. If, however, the weight of air used per lb. of fuel burnt be known, the furnace temperature can be calculated by aid of the specific heat value for the waste gases. This is the more convenient and usual plan for ascertaining furnace temperatures.

One lb. of average coal requires theoretically 12 lbs. of air for its complete combustion, and yields 13 lbs. of waste gases. The specific heat of these exit gases lies between 0·239 and 0·316 (the latter is the value given by Poole in his book on Fuel), and for the purposes of this calculation it may be taken at 0·250.

Assuming, then, that the fuel has a calorific value of 8,000 lb.-Centigrade units, the maximum temperature attainable by its complete combustion in air would be :

$$\frac{8000}{13 \times 0{\cdot}250} = 2{,}460° \text{ C., or } 4{,}460° \text{ F.}$$

This temperature is, of course, never attained, the chief reason for the failure being that complete combustion of solid fuel is impossible without an excess of air. The air used is usually 100 per cent. above that theoretically necessary, and only in scientifically controlled boiler plants is this excess reduced to a minimum.

Taking, now, the usual conditions under which an excess of 100 per cent. is regularly

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allowed to pass through the boiler furnaces (equivalent to 25 lbs. of exit gases per lb. of fuel burnt), we find the temperature attainable by the combustion of the above fuel is:

$$\frac{8000}{25 \times 0{\cdot}250} = 1{,}280^\circ \text{ C. or } 2{,}336^\circ \text{ F.}$$

This temperature is little more than one-half of the maximum.

The highest practicable temperature in ordinary boiler furnaces is that represented by 14 per cent. CO_2, or 17·2 lbs. of exit gases per lb. of fuel burnt. These figures give a temperature of 1,860° C., or 3,380° F., when calculated out by the method used above. This limit is rarely exceeded under normal conditions of work, unless a pre-heated air supply be used. Should, however, such a system of air heating be employed, the final temperature is raised by nearly the same number of degrees as the gain in temperature of the air supply. If the air enters the furnace at 365° F., in place of 65° F., the temperature actually attained in the furnace will be about 300° F. higher than when cold air is employed.

The advantages of obtaining as high a temperature as possible in the boiler-furnace are twofold. In the first place, in all plants working with chimney draft (miscalled "natural draft") a certain fixed loss of heat occurs with the exit gases, for the suction of the chimney depends upon the difference in temperature between the gases passing up it and the surrounding air. It is, therefore, impossible, with chimney draft, to reduce these exit gases below a definite limit of temperature, which for most plants is about 400° F. Now it is evident, if the actual temperature attained in the boiler-furnace be 3,600° F., that the loss of heat in the exit gases cannot exceed 400/3,600, or one-ninth of the total heat generated. Supposing, however, that owing to the use of a large excess of air, the temperature actually attained in the furnace is only 2,400° F.; then the loss of heat in the exit gases rises to 400/2,400, or one-sixth, and the heat efficiency of the whole plant is diminished by 6 per cent.

The second advantage resulting from the use of a high furnace temperature is that it promotes the transfer of heat to the water. The rate of heat transfer through a boiler-plate is dependent upon the difference in temperature between the hot gases and the water, and varies practically with this difference. *The rate of heat transfer is consequently the greater, the higher the furnace temperature.* The efficiency of the boiler plant is therefore promoted by the attainment of the highest possible temperature in the combustion chambers of the furnace, since by such means the chimney losses are reduced, and the rate of heat transfer is increased.

Another method of increasing the temperature attainable by the combustion of solid fuel in the furnaces of steam boilers, is to use air under pressure for supply of the furnaces. F. J. Rowan, in a recent article, has discussed the gain that could be obtained by this method of working, and has shown that, with air at two atmospheres pressure, the gain in temperature would be 715° F., and that at three atmospheres pressure the gain would be 1,208° F. These gains are due to the fact that the specific heat of a gas at constant volume is much less than that at constant pressure, since heat is absorbed when expansion of the gas occurs. The specific heat of the exit gases at constant volume would be about 0·180 instead of 0·250; the corresponding gain in the final temperature can be ascertained by the methods of calculation already used. The present writer believes, with Rowan, that more will be heard of this method of increasing the temperature of combustion in boiler furnaces, and therefore of the efficiency of the boiler installation.

Heat-Transfer.

It has already been pointed out that the rate at which heat passes through a boiler-plate is dependent upon the difference of temperature between its two sides. It was at one time considered that the rate of heat transmission was proportional to the square of the difference of temperature between the hot gases on one side of the plate and the water on the other; but Stromeyer considers this law incorrect, and gives figures in a recent publication,* showing that the transmission is directly proportional to the difference of temperature between the two sides of the plate. Using this law, he gives the following figures for various types of boilers:—

Type of Boiler.	British Thermal Units transmitted per hour per sq. ft. per 1° F. difference of temperature between opposite sides of the plate.
Marine boiler . . .	5·55
Loco-portable boiler .	5·21
Lanc. & Cornish boilers	5·05
Water-tube boilers . .	5·26
Economisers	2·79

* Memorandum to the Manchester Steam-Users Association. 1902.

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Miss Bryant has also carried out investigations on heat transfer through metal plates, and has proved that, in order to evaporate 50 lbs. of water per sq. foot of heating surface, a half-inch plate will require heating and maintaining at 150° C. or 302° F. Now the latent heat of steam is 965·7 B. Th. units, and 50 × 965·7 = 48,285 B. Th. units, equivalent to a temperature of 48,285/5·05 = 9,657° F. But Miss Bryant has shown that this rate of evaporation demands a temperature difference between the two sides of the plate of only 90° F., therefore the rate of heat transmission evidently increases enormously with the increase of temperature.

As a matter of fact, experimental results have been obtained with many thicknesses of boiler-plates and tubes, showing that water can be evaporated at rates up to 70 lbs. per sq. foot of surface per hour, without danger of overheating, so long as the plates are sound, clean, and free from grease; and at this rate of evaporation Miss Bryant found a difference of temperature between the two sides of the plate of only 70° C. or 158° F.

A simple experiment, which shows how low is the temperature of a water-cooled surface, is to boil water over a candle flame in a paper cup or vessel. So long as the flame is allowed to be in contact only with the bottom of the vessel, and this is kept covered with water, no charring or burning occurs, and the water can quite easily be raised to boiling-point without damage to the paper. The small paper caps used by chemists to cover the corks of medicine bottles, or the larger cups sold for containing ice-cream, serve well for this experiment, which, though simple, is exceedingly instructive.

The rate of heat transfer through metal-plates up to one inch in thickness is therefore a function of the temperature, and increases enormously as the temperature difference between the flame and hot gases on one side of the plate and the water on the other, grows larger. No danger due to the plates becoming red-hot can occur so long as these are clean, free from grease, and are well covered with water in free circulation.

The case becomes otherwise, however, when the water side of the plates is covered with scale or grease deposits. Although the popular idea that scale is a very bad conductor of heat is probably erroneous, some action occurs which leads to overheating of the plates, and many boiler accidents and explosions have been traced to this cause. Still more dangerous are the deposits of oily and fatty matters, which are sometimes found with the scale in boilers fed with dirty and greasy water. In these cases the cause of overheating is probably the presence of a slight cushion or film of superheated steam between the boiler plate and the scale or greasy deposit; as this steam is unable to escape, overheating of the plates is bound to occur.

Turning now to a consideration of the transfer of heat from the boiler plate to the water, Fig. 1 shows in a striking manner the great absorptive power of water for heat, and the very large amount of latent energy which is contained in 1 lb. of steam at 212° F. The suitability of water as a liquid for conversion into a vapour which should be employed for driving engines, is well brought out in this diagram.

The vertical divisions of the diagram represent the temperature in degrees Fahrenite, and the horizontal divisions the amount of heat in British Thermal units. Starting at the point A, the line A B shows the rise in temperature of 1 lb. of ice, for successive increments of B. Th. units, from the absolute zero of temperature to + 32° F., when it commences to melt.

The latent heat of water is 142·2 thermal units, and the temperature of the half-melted mixture of ice and water remains constant, and is denoted by the horizontal line B C, while this amount of heat is absorbed. A rise in temperature then again occurs, until 212° F. is reached, 180 thermal units being absorbed before this point is reached. The line C D indicates this rise in temperature. Then another 965·7 thermal units are absorbed, or rendered latent, before the 1 lb. of water at 212° F. is converted into steam at the same temperature, and the horizontal line D E indicates this disappearance of thermal units, without any corresponding rise in temperature. The last section, E F, of the curve shows the rise in temperature which follows further addition of heat to the steam, the rise being more rapid than for ice or for water, owing to the lower specific heat of the steam, which varies from 0·47 to 0·65, according to the pressure. The dotted lines B G and D H show the temperature rise which would have occurred had there been no heat absorption at the points B and D; the line A K shows the corresponding rise of temperature when steel is heated.

The amount of heat which is required to convert 1 lb. of water into steam at a temperature of 600° F. is, therefore, more than four times that required to melt 1 lb. of solid steel, and had there been no change of state in the

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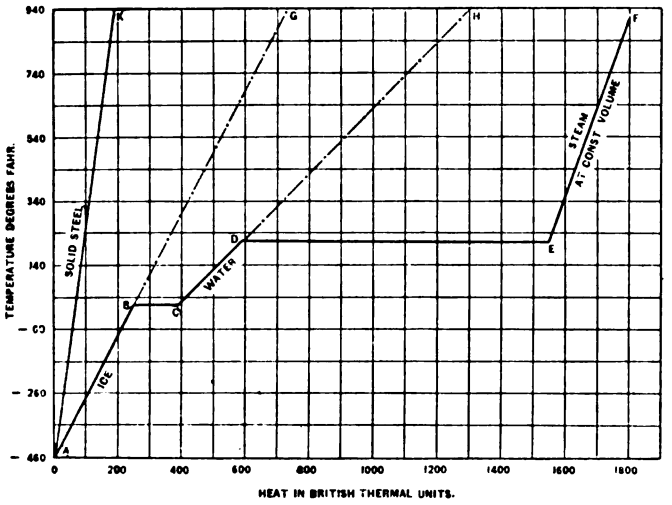

FIG. 1.—TO ILLUSTRATE THE HEAT CONTAINED BY ONE POUND OF STEAM.

case of ice and water, this amount of heat would have produced a temperature of over 2,600° F. in the final solid or liquid. A great amount of heat energy is thus present in 1 lb. of steam at 212° F.—an amount more than five times that required to raise 1 lb. of water from 32° to 212° F., and it is this large reserve of heat within reasonable temperature limits that renders steam such a useful fluid for expansion work, in a steam engine cylinder.

As regards the actual production of steam within the boiler, it may be remarked that any feature of boiler design or structure that facilitates the formation of steam bubbles, and their escape from the heated plate at the earliest possible moment, is of advantage and promotes economical operation of the plant.

An interesting experiment is to fill a cubical box made of thin steel sheet with glowing coke, and to suspend this box in hot water contained in a glass vessel, in such a manner that its six sides are covered with the water. It will be found that the volume of steam generated from the upper surface will be much greater than that generated from any of the four sides, and that little or no steam will be generated from the bottom surface of the box. Should half the upper surface of the box be roughened by a sand blast, and the other half polished, it will be found that steam escapes most rapidly and in smaller bubbles from the first, since there is less cohesion between the steam and the roughened surface, and less force is required to carry it up and away from the heated surface. Metal points and projections act in the same manner. The more quickly the steam bubbles are removed from the heated boiler plates, and their place taken by hot water, the greater is the amount of heat which will pass through the plates to the water; thus it follows that a well-designed boiler should possess as many roughened horizontal surfaces with water above them, as possible; and that perfectly smooth vertical, or re-curving surfaces, should be avoided near the fire-box or flues.

How far the modern Lancashire and water-tube boilers fulfil these conditions, will be discussed in a later article of this series.

EFFICIENCY CALCULATIONS.

It has been pointed out that the approximate analysis of fuel enables the engineer in charge to calculate the amount of heat which will be generated by its combustion, and that analysis of the exit gases enables him to calculate the excess of air which is being passed through the fires and up the chimney. With these data, combined with temperature observations of the air and exit gases continually before him, it is possible to keep a fairly accurate check upon the efficiency of the boiler plant; for the heat losses by radiation and by the unburnt cinders and ashes are fairly constant, and may be included as a fixed loss of 15 per cent. in regular work.

A heat-balance for the boiler installation can therefore be made up daily, with little trouble, from the results of the chemical tests.

The following is an example of this method of checking the working efficiency of a boiler installation:—

Fuel.—Lancashire slack at 7*s.* 6*d.* per ton delivered in bunkers. Heat units produced per lb. by calorimeter test, 13,500 B. Th. U.

1. Losses by radiation, etc. (10%) .	1,350
2. Losses with exit gases up the chimney (calculated) 10% CO_2, and gases at 465° F. . . .	2,380
3. Losses by unburnt carbon in cinders and ashes, and heat carried away in same (5%)	675
4. Converted into steam in boilers (by difference)	9,095
	13,500

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The efficiency of the plant, therefore, equals 9,095/13,500 or 67%. Items 1 and 3 are based on estimates or upon previous test results; but these two items, under ordinary working conditions, should not vary more than 5 per cent.

Should the analysis of the exit gases show that carbonic oxide gas is present, a further entry will be necessary in the above heat balance, to show the thermal units lost by this failure to burn all the carbon to carbon dioxide. Let us take, as an example of this additional calculation, exit gases containing 2 per cent. by volume of CO, and 8 per cent. CO_2. Since carbon, when burnt to carbon dioxide, yields the same volume of gas as when burnt only to carbon monoxide, the above percentages show that $\frac{2}{10}$, or one-fifth of the carbon present in the fuel, has escaped complete combustion. Now, as found by the approximate analysis, the percentage of fixed carbon present in the fuel was 60 per cent., and the thermal units liberated when carbon is burned to CO are 10,201 less than when carbon is burned to CO_2 (4,343 and 14,544 respectively.)

The loss of heat due to incomplete combustion, in the case under consideration, is therefore :—

$0{\cdot}60 \times \frac{1}{5} \times 10{,}201 = 1{,}224$ B.Th. units, and the efficiency of the boilers is reduced to 58 per cent. in consequence of this incomplete combustion of a portion of the fuel.

This additional loss is a considerable amount of the total heat energy of the fuel (9%), and the calculation shows the necessity for keeping a close check upon the presence of CO in the exit gases.

Since the automatic recording instruments now in general use for checking the composition of the exit-gases from steam-boiler plants do not record the presence of CO, it is evident that independent tests with an Orsat apparatus ought at times to be made, in order to check the presence or absence of CO. This gas is most likely to be present when attempts are being made to work with a minimum of air and thick fires, in order to attain a high percentage of CO_2 in the exit gases; thus, efforts to reduce the heat losses due to excess of air, unless under a chemist's control, may result in very considerable heat losses in another direction. The need for expert scientific control of the testing work is therefore apparent, and automatic testing apparatus, though useful, is not an efficient substitute for the trained chemist.

The subject of gas-testing will be dealt with at length in Article V. of this series; but it may be pointed out here, that as fuel and gas analysis enables one with ease and a fair degree of accuracy to determine the thermal efficiency of the whole boiler installation, it is deserving of more attention than has yet been accorded to it by engineers in charge of boiler-plants. In fact, these test results enable one, at a moderate expense, to achieve daily or weekly what at present is only carried out at long intervals of time, and with much disturbance to the usual routine, under conditions of working which cannot be regarded as normal. The money now expended upon special steam-raising and efficiency trials, if expended in the way suggested upon regular testing work would lead, in the author's opinion, to far more valuable results, and to a far better average of efficiency, than is attained under the present system. No doubt in time, the value of fuel and gas analysis in controlling the work of boiler installations will be fully recognised. This work must be carried out, however, under expert control, for the results obtained from it to be of real value.

(*To be continued.*)

EFFECT OF ULTRA-VIOLET LIGHT ON GLASS.

In a paper contributed to the *Physikalische Zeitschrift* for April 1st, 1905, F. Fischer describes experiments made in order to determine the effects of ultra-violet light on glass. The light was produced by a mercury arc lamp in a quartz tube; it was found that four out of eight glasses examined acquired a slight colouration after being placed near the tube for a quarter of an hour, and an intense violet hue was produced in twelve hours. The colour was found to be due to the presence of manganese silicate in the glass. Sir William Crookes recently found that certain kinds of glass acquired a violet colouration when exposed to sunlight at Uyini, Bolivia, situated 4,000 meters above the sea level.

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ARMOURED CONCRETE.

PART II.

By Lieut. HENRY J. JONES, A.O.D., A.R.C.Sc. (Lond.), Inspector of Ordnance Machinery.

BEFORE discussing the systems and methods of design used in connection with armoured concrete, it is obvious that a statement must be made concerning the properties of the materials which we propose to use. Steel is so common and familiar as to need no description; nevertheless it is to be remembered that, in the absence of experimental evidence, we are ignorant as to how the properties of steel may be modified by its being embedded in concrete. What is the effect of this on the elastic properties of steel? How is the initial state of the steel affected by subsequent shrinkage of the concrete? These are questions which experiment, and experiment alone, can answer; in the meantime we must use a large "factor of ignorance" to cover eventualities. So far as we are immediately concerned, the only fact of importance is, that the adhesion between steel and the concrete which has set round it varies from 550 to 680 lbs. per square inch; and as this is above the safe compressive stress for the concrete, we are justified in assuming that failure will not occur through slip between the steel and the concrete. Even were this coefficient of adhesion in dispute, it would be sufficient to know that experiments have repeatedly shown that armoured concrete beams admit of distortion and ultimate fracture without the continuity of metal and concrete being destroyed. The steel should be of the best quality, and capable of being worked to 7½ tons per square inch.

The sections of the steel employed vary in different systems, being round, flat, square, angle, and tee. In all cases the simplest section is the best, as it costs less, and readily allows the concrete to be rammed into the closest contact with the entire surface of the armouring. Small sections are better than large ones, as by their use we can get a more uniform distribution of stress in the steel; we can also readily bend and work them into any required shape; and finally, the most economical disposition of material is obtained, the metal being placed at the maximum distance from the neutral axis. Care should always be taken that there is a good protective covering of concrete external to the armouring; the thickness of this covering should never be less than from one to two inches.

Expanded metal meshing is being increasingly employed, more particularly in the lighter forms of construction. It consists of sheets of metal which have been mechanically slit and expanded, so as to produce a network. This type of armouring has many and obvious advantages. Its mere existence is proof of good steel, and it forms an excellent key to thicknesses of concrete too thin to allow of the armouring being in the form of rods; thus it is very useful for concrete plaster, ceiling, and partition wall work. The overlapping of two sheets of metal for a few inches, before the concrete is laid, is sufficient to securely unite them; and the arrangement of armouring in sheets secures the great advantage of longitudinal and transverse strength, which greatly increases the adhesion and strengthens the concrete against shear.

Concrete has long had the reputation of being erratic in its behaviour, but strict inquiry into the cause of its many failures has revealed these to be due to bad workmanship or inferior materials. In some cases the aggregate was either too large or too small, or was composed of flinty materials which fractured under the slightest provocation; in cases where care had been taken to secure a suitable aggregate, it was used either in an unclean state, or had too much or too little water added in the mixing. But by far the greatest number of failures have been due to the inferior quality of the cement. The use of unsuitable cement must be attributed either to laxity in its testing, or faultiness in the specification under which it was supplied.

Good cement is absolutely necessary for armoured concrete. At present we can get English Portland cement, which will leave no residue on a 76 × 76 sieve, wire 0·005 inches diameter, and only 10 per cent. on a 180 × 180 sieve, wire 0·0025 inches diameter. In any case, it should be specified to leave no more than 5 per cent. on a 120 × 120 sieve, wire 0·0035 inches diameter. Slow-setting cement is best; pats made with the minimum amount of water should set in not less than five hours when the temperature is 35° F., and not less than twenty minutes at 75° F. The aggregate, when used for floors, columns, walls, etc., should all pass through a ¾-inch ring, and a one-inch ring for footings; it should be quite clean, the proportions of sand and stone being adjusted to give a con-

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crete quite full. The concrete should always be used in small quantities, so that after rolling or ramming no porosity may be possible. The sand should be clean and sharp, free from loam and all other impurities, the grains varying from $\frac{1}{4}$ inch down to the smallest size obtainable at a reasonable cost. The proportions of cement, sand, and stone should not be less than 1 : 2 : 4 for columns and girders; and 1 : $2\frac{1}{2}$: 5 for walls, floors, and footings.

The best plan is to do the mixing and laying as rapidly as possible; if the concrete is made moderately wet, the ramming should be continued until water appears at the surface. When the concrete has been laid and rammed to the specified dimensions, the shuttering should not be disturbed for at least three or four weeks, depending on the temperature. In all cases the shuttering must be well braced and supported, so as to guard against undue deflection when the concrete is deposited. To give a good finish to the work, the shuttering should be quite true to the required shape, and have the working faces planed smooth and covered with soap or grease, so as to prevent sticking. After the concrete has set and the shuttering has been removed, at least 5 per cent. of the girders should be tested with a load 50 per cent. above the maximum working load, and the maximum deflection should not be more than from $\frac{1}{800}$th to $\frac{1}{600}$th of the span. Piles should be left in their forms at least four weeks before use, and longer if possible.

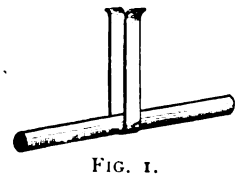

Fig. 1.
Hennebique Stirrup.

The safe compressive stress of concrete depends upon the quality and quantity of the cement, the nature and size of the aggregate, and particularly upon the skill exercised in the manufacture, and care in the use of the concrete. It is interesting to note that the compressive strength of concrete increases with age. Experience indicates that for piles, arches, walls, foundations, etc., which are subject to direct pressure, we may assume a safe working stress between 350 and 550 lbs. per square inch. For beams, floor slabs, roofs, etc., 450 to 650 lbs. per square inch may be taken. Concrete has little strength in tension or in shear; if necessary, we may safely assume the former to be from 30 to 60 and the latter from 20 to 30 lbs. to the square inch. In carrying out calculations, it is usual to neglect both the tensile and shear strength in the most approved designs; provision is afterwards made to take tensile and shear stresses by a suitable disposition of rods and stirrups. In the Hennebique system stirrups are used, as indicated in Fig. 1; these are spaced from four to twelve inch centres along the rods, being closest where the shearing forces are most intense. Fig. 2 shows the arrangement of these stirrups in cross girders and floors. The necessity for these stirrups is proved by the fact that concrete ribs do not show the first signs of failure at their mid-points, where the tensile stresses are a maximum, but nearer the supports; the failure of the rib is indicated by diagonal cracks which arise from the combined action of the tensile and shearing stresses.

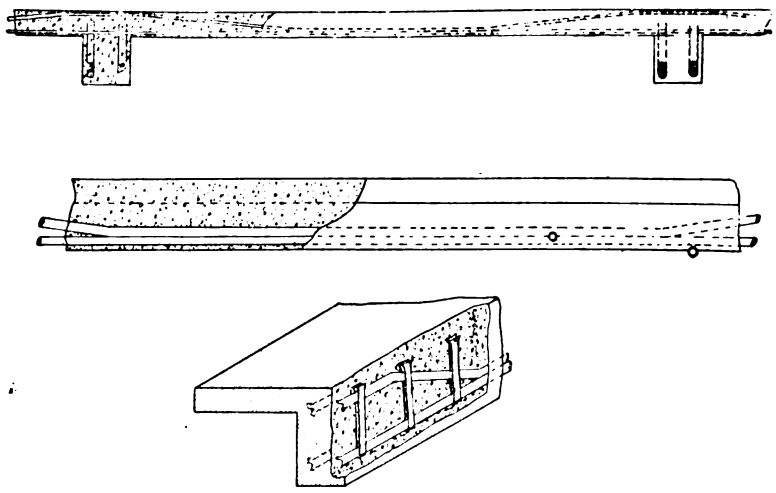

Fig. 2.—Rods and Stirrups applied to Floor and Girders.

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Columns and Piles.

Armoured concrete columns are made with either square, rectangular, or circular sections; when well-proportioned, the height of a column should not exceed fifteen times the diameter of its equivalent circular section. They are armoured with from four to twenty rods, the diameters of which vary from $\frac{3}{8}$ to $2\frac{1}{2}$ inches.

The rods are placed as near as practicable to the circumference of the column, so as to give the greatest radius of gyration for the section; but, as stated above, they should never be placed so near the surface that they have not at least one or two inches protective covering. The steel so disposed is able to take up the tensile stresses which may be induced in the column by eccentric loading, lateral shock, wind pressure, and the pull of belting.

The following table gives the maximum load which square columns will carry when the height does not exceed fifteen diameters. The percentage of steel exposed in cross section is never above 5 per cent., and is usually about $2\frac{1}{2}$ per cent.

Section of Column in Inches.	Safe Load in Tons.	Section of Column in Inches.	Safe Load in Tons.
8 × 8	40	24 × 24	380
10 × 10	63	26 × 26	450
12 × 12	96	28 × 28	525
14 × 14	130	30 × 30	605
16 × 16	170	32 × 32	670
18 × 18	215	34 × 34	745
20 × 20	270	36 × 36	800
22 × 22	320	38 × 38	900

Columns and piles are made in wooden boxes, each consisting of three permanent sides, and a fourth side which is temporary and removable. Under the patent rights of François Hennebique the armouring is placed in these boxes, and adjusted by gauges to be within one or two inches of the sides. The concrete is laid and rammed, about six inches at a time, with special small hand rammers. The open side of the box is built up by battens fitting into grooves in the permanent sides, as the work proceeds; this enables inspection of the work to be made, and facilitates the placing of the ties at the proper positions.

The ties are made of round wire $\frac{3}{16}$ inch diameter, and are dropped down over the top of the steel rods. They are spaced from two-inch centres at the bottom and top, to twelve-inch centres in the centre of length of the column, and are intended to prevent the steel rods from spreading out under the action of longitudinal loads. Fig. 3 shows the method of joining columns to the floor.

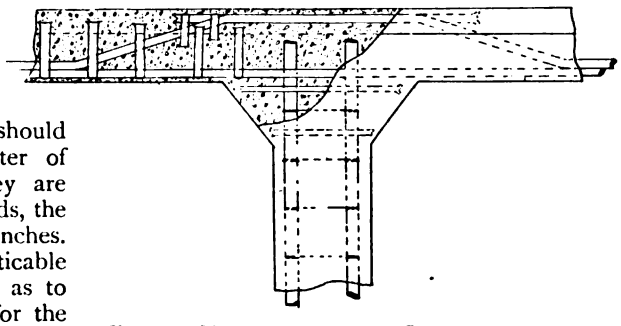

Fig. 3.—Method of joining Column to Floor.

The Considere columns are very interesting. They are built on the same principle as wire guns, and consist of a circular concrete core wound with spirals of steel wire, the pitch of which is from one-seventh to one-tenth the diameter of the core. The whole is then covered with a layer of concrete, about two inches in thickness. These columns of Considere, when without longitudinal armouring, have an ultimate resistance of from 12,000 to 15,000 lbs. per square inch, and if longitudinal armouring be introduced as well, we may safely work them to 6,000 lbs. per square inch. These columns are very suitable for heavy loads, but are somewhat costly; for light loads the ordinary columns are preferable. It is a well-known fact that on setting in air, concrete shrinks; hence, when using longitudinal armouring, the concrete adhering to the steel is put in tension and the steel in compression. This action may be very severe, so much so that the elastic limit of the materials may have been reached even before the load comes on. In the case of spiral armouring, however, the shrinking of the concrete puts the steel in compression; when the load comes on, the spirals, tending to expand, are put in tension, and a state of molecular equilibrium is reached when the compressive stresses induced by the shrinking of the concrete are just neutralised by the tensile stresses induced by the loading. Afterwards we have the whole tensile strength of the armouring available for any increased tensile stress induced by additional loading.

Piles are usually made in vertical moulds, but are equally good when made horizontally. They constitute quite a unique feature of armoured concrete construction, proving beyond all possible doubt that such a system is able to stand repeated shock without disintegration or dissociation of the steel and concrete. The pile carries a shoe with a

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chilled cast-iron point, and side plates of wrought iron to lock it to the concrete. The head of the pile is reduced in width to give a clearance, between adjacent piles, for the driving cap. This cap is of cast steel; it fits loosely over the head of the pile, being filled with sand or sawdust, and closed at its lower end by a clay ring held by a plug of yarn. This arrangement ensures a very uniform blow being given to the pile head; it also

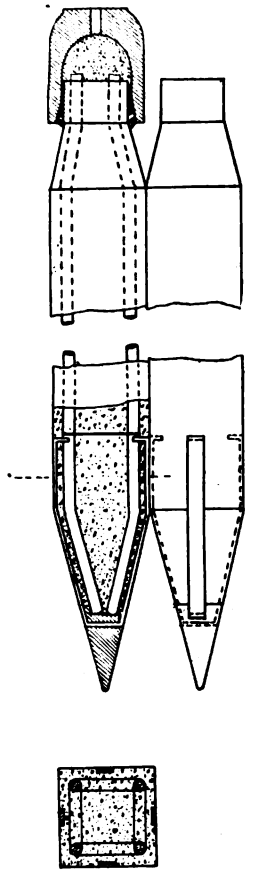

FIG. 4.—ARMOURING FOR A 12-IN. × 12-IN. KING PILE.

allows the armouring to project beyond the concrete, to be connected to other parts of the structure, or to be bent into hook-shape for convenience of handling. A section and elevation of a 12 × 12 pile is shown in Fig. 4.

Sheet piles are strengthened by rods clamped and cross-tied. They carry cast-iron shoes and wrought-iron locking straps, the heads being reduced to receive a driving cap. A projection is often cast on one pile to work in a groove cast in another. This ensures a straight drive, and a good joint

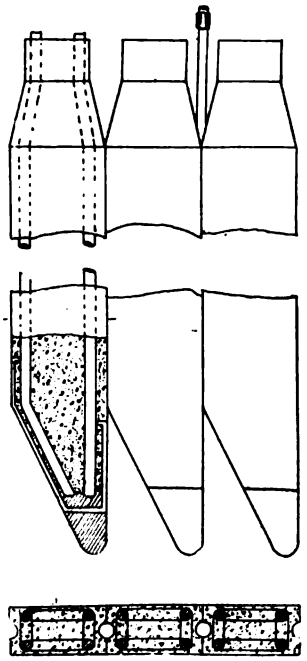

FIG. 5.—ARMOURING FOR A 12-IN. × 6-IN. SHEET PILE.

between successive piles. A special arrangement is sometimes used; an iron pipe is made to fit into a groove in the pile last driven, and another in the pile which is being driven; this pipe is connected to a powerful water pump, and not only serves to guide the piles, but also delivers water at a high pressure, which forces out the mud and sand, and prevents the jambing of the piles. When the piles are driven, the pipe is withdrawn and cement is run into the open groove, which, on setting, forms a very perfect joint. Fig. 5 shows the arrangement of armouring in sheet piles.

Piles up to sixty feet in length are now in use. The requisite cross-sectional area depends on the load to be carried and the nature of the site. The metal exposed in cross-section varies from 2 to 5 per cent., and is invariably of round rods, clamped and tied as in the columns.

The following table gives particulars of Hennebique piles made and used at Southampton :—

Section of Pile in Inches.	Armouring.	Percentage of Steel in Cross-Section.
12 × 12	4 rods 1½ inches diam.	5
14 × 14	,, 1¼ ,, ,,	2½
15 × 15	,, 1⅜ ,, ,,	2½
16 × 12	,, 1⅜ ,, ,,	4¼

(To be continued.)

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STEEL PURLINS FOR CORRUGATED IRON ROOFS, IN THEORY AND IN PRACTICE.

By E. FIANDER ETCHELLS, A.M.I.Mech.E., F.Ph.S.

THE young theorist and the old workman have wrangled together, and have thereby increased their mutual scorn. In the old case of theory *v.* practice, as to the correct dimensions of roof purlins, Time the Arbiter has deferred his award. Therefore I beg leave to intervene and invite the contending parties to come to some mutually advantageous arrangement pending the final decision, for when Theory and Practice differ, Time alone can give us truth.

It will be necessary, in the first instance, to ascertain the extent of the difference. The old workman will tell us of purlins so light and spans so long that the unpractical theorist is nonplussed. Further, Mr. Alexander Drew, C.E., M.I.Mech.E., consulting engineer, Westminster, will support the old workman in stating that "for a sheeted roof with trusses 15 feet apart and purlins up to 8 feet apart, 3-inch × 3-inch × $\frac{3}{8}$-inch angles will prove sufficient."

Let us calculate the strength of this purlin by the ordinary theory. Assume that the slope of the roof is 30°. With horizontal wind at 40 lbs. per sq. foot, the pressure perpendicular to the roof = 0·66 × 40 = 26·4 lbs. per sq. foot (Hutton). Let 3·6 lbs. per sq. foot be allowed for the normal component of the weight of corrugated sheeting and dead weight of purlins, etc.

Then the total pressure perpendicular to the surface of the roof will be 26·4 + 3·6 = 30 lbs. per sq. foot of sloping surface. The load carried by each 3 × 3 angle purlin will be 15 × 8 × 30 = 3,600 pounds = 1·6 tons.

If the purlin be 30 feet long and trusses 15 feet apart, the maximum bending moment will be at 15 feet from the end, and will be $\frac{W l}{8}$ ton-inches.

$$\frac{W l}{8} = \frac{1{\cdot}6 \text{ tons} \times (15 \times 12)}{8} \text{ inches}$$

$$= 36 \text{ ton-inches.}$$

Let Z = Section modulus (*i.e.*, the moment of resistance at unit stress on the extreme fibres).

„ f = The estimated stress on the extreme fibres, in tons per sq. inch.

The moment of resistance = Zf

$$\frac{W l}{8} = Zf,$$

i.e., 36 ton-ins. = Zf;

$$\therefore \frac{36 \text{ ton-ins.}}{Z \text{ ins.}^3} = f \text{ tons per sq. inch.}$$

For a 3-inch × 3-inch × $\frac{3}{8}$-inch angle section with the vertical axis parallel to one limb, Z = 0·8 (inches)^3 very nearly;

$$\therefore f = \frac{36}{0{\cdot}8} = 45 \text{ tons per sq. inch.}$$

The ultimate statistical tensile strength of the quality of steel used is between twenty-eight and thirty-two tons per square inch. Here, then, is the anomaly—roofs stand the gales of years, and yet the estimated stress exceeds the actual breaking stress by about 50 per cent.

Suppose the purlins were only four feet apart, the stress would still appear to be about 22·5 tons per square inch. This stress is higher than the elastic limit of the material, yet the purlins show no injury.

What is the explanation? Is there anything wrong with the accepted theory?

The theorist is apt to forget that the best modern practice represents the accumulated experience of countless generations of builders—an international experience which has been gained through the storms and tempests of the ages, for storms are self-appointed examiners in construction to the practical man: they pick out all his faulty examples of construction, hurl them down, and carry them away. The theorist forgets that "theories are but theories," and need to be tested at every stage by rigorous practical experiment. After all, what is a theory but "a supposition explaining something; a doctrine resting merely on speculation?"

It is common knowledge that some theories have been tested and accepted as true, but these are more correctly termed theorems.

A theorem may be defined as "a position laid down as an acknowledged truth or established principle."

The "practical" man does not discriminate between a theory and a theorem. He is apt to look at them in the mass and despise them all.

Theories, again, may be subdivided into

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good, bad, and indifferent, and here it is the theorist himself who is not very discriminating. He is continually building on theories which are right in themselves, but are not applicable to the work in hand. The theorist should at all times ascertain, as far as possible, what assumptions underlie his calculations.

In the case of the purlins, the assumptions we have made are the usual ones, and include the following :—

1. That the purlin is rigidly fixed at one end and freely supported at the other.

2. That the direction of the wind is horizontal.

3. That the wind acts as a steady uniform pressure over a surface of 15 ft. × 8 ft.

4. That the intensity of the wind pressure is 40 lbs. per square foot over large surfaces.

5. That the ordinary beam theory is applicable to a purlin.

6. That the purlin is not weakened by the rivet-holes at the connections to the trusses (*i.e.* we made no deductions from the Section Modulus).

Here are six assumptions selected at random. How many of them are tenable or reasonable? They are all more or less of the nature of approximations, and, in fact, some of them are merely working hypotheses. Now the question arises, are they the closest approximations we can get to the truth?

Assumption No. 1 comes nearest to the truth when the length of the purlin is twice the distance between the trusses, and when there is only one rivet at each end of a purlin. In this case the maximum bending moment $= \frac{1}{8} W l$. If both ends of the purlin were fixed in direction, the maximum bending moment would be considerably reduced, and smaller sections could be used. Therefore I advocate that each end of a purlin should be fixed by at least two rivets. In this case all the spans of the purlins will be in the condition of beams with fixed ends.

Assumption No. 2 refers to the direction of the wind. The ruling direction of the wind is admittedly essentially horizontal, but the wind striking the walls of a long building must be deflected from its straight course, and this will prevent the wind striking the roof in an horizontal direction. On the other hand, the disposition of surrounding objects may cause the wind to beat down on to the roof of a building.

Both these circumstances are usually neglected in calculations, and of course vitiate our results.

Assumption No. 3, that the wind acts as a steady uniform pressure. It is of course possible for the wind to act thus, but even in great gales it usually acts in sudden gusts and swirls; therefore assumption No. 3 is more convenient than accurate.

Assumption No. 4, that the intensity of the wind is 40 lbs. per square foot over large surfaces. 40 lbs. is manifestly an approximation. Why not 39·9? Why not 40·1?

Again it is an admitted fact—a theory which has been tested at the bar of practical experience and experiment—that the average intensity of the wind pressure over large surfaces is considerably less than the average pressure over a smaller surface.

"Whilst the maximum pressure on a one-foot anemometer at the Forth Bridge was 31 lbs. per square foot, the average over a board of 300 square feet was 19 lbs. only." [Sir Benjamin Baker.]

Experiments are also being made at the present time by Dr. Glazebrook at the National Physical Laboratory, Bushey Park, on boards of 5 square feet and 50 square feet area respectively.

Assumption No. 5, as to the applicability of beam formulæ. The great discrepancy between the ordinary theory and the general light practice with regard to steel purlins has led me to speculate whether the purlin does not carry its load either wholly or partially as a catenary, or flexible uniformly loaded chain; somewhat similarly, say, to the cable of a suspension bridge.

The objection to this theory is that, although it gives reasonable results so far as regards the size of purlins and purlin rivets, it leads to the assumption that the reactions are provided for by lateral bending stresses in the rafters on the windward side of the trusses at the gable ends. This latter assumption cannot be maintained. We are therefore compelled to fall back upon some modification of our beam theory.

With regard to assumption No. 6, if the purlin act as a beam, the rivets at the connections will pass through the purlin very near the neutral axis, and the loss of strength will not be serious, and in practice may be neglected.

Having dealt in detail with some of the faults and assumptions of the common theoretical method, I propose to show how an imperfect theory can be improved and made more acceptable to those who have had extended experience in the practical work of designing, erecting, and maintaining well-constructed steel buildings.

My apology for writing at such length is

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that book information as to purlins is remarkably scanty, and usually very vague and indefinite. I propose to develop and establish a general rule readily applicable for all ordinary cases.

In the first place, take a detached building with two or three roof-trusses, and a detached building with, say, nine, ten, or more trusses. In the shorter building the wind can escape round the ends much more readily than in the longer building. Therefore let us confine our attention to the longer building.

Assume two rivets in the end of each purlin, so that the ends of the purlins may be fixed in direction. The purlins are then like continuous girders.

Let L = the length of the span in feet, *i.e.*, the distance between the trusses.

D = the distance between the parallel lines of purlins (in feet).

The sloping area supported by each purlin

$$= LD \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The dead loads are made up as follows:—

	lbs. per sq. foot of sloping area.
Corrugated iron, 18 B.W.G.	= 2·6
Allowance for laps and rivets 10%	= 0·26
Allowance for weight of purlin	= 1·00
	3·86

This 3·86 is a vertical force. It may be resolved into two components: one normal to the surface of the roof, and the other parallel to the surface of the roof.

The component parallel to the surface of the roof is most probably taken up by the sheets themselves, since it is practically a force acting down the roof—along the corrugations, as it were. For a force in this direction, a corrugated sheet becomes virtually an exceedingly stiff plate girder.

If the roof be inclined at 30° to the horizontal, then the normal component will be found to be:—

$$3{\cdot}86 \times \cos 30^\circ$$
$$= 3{\cdot}86 \times 0{\cdot}866$$
$$= 3{\cdot}34 \text{ lbs.} \quad . \quad . \quad (2)$$

This may be easily verified by drawing the triangle of forces. To this normal component of the dead weight we must add the normal component of the wind pressure. What wind pressure shall we take?

"At the Leven Viaduct, to the north of Morecambe Bay, the wind has a clear sweep over the perfectly level surface of the bay for quite 20 miles. The viaduct consists of iron girders supported on cast-iron piles. It has no parapets, so that trains catch the full force of the wind for their whole height. On February 27th, 1903, a train was standing on the viaduct, when all the carriages save the one next to the engine were overturned by the force of the wind. The carriage next to the engine was held up by the coupling.

"At the time of the accident the rail level was about 28 feet above the surface of the water. The stiffest vehicle was a London and North Western bogie-brake, which would require a pressure of 42 lbs. per square foot to overturn; and the lightest vehicles were four-wheel coaches, which would overturn with a horizontal pressure of 32 lbs. per square foot." (*Vide* Board of Trade Report.)

We have here incontrovertible evidence of a wind pressure of at least 32 lbs. per square foot over a surface larger than any anemometer.

I do not think we can take these facts as evidence of a pressure as high as 42 lbs. per square foot. Since the carriage next to the engine was restrained by the greater stability of the engine, it is clear that the end carriage must have *tended* to pull the engine over.

In a similar manner the light four-wheel coaches may have assisted in overturning the stiff London and North-Western bogie brake. On the other hand, if the lighter vehicles were steadied by the heavier ones, a pressure of 32 lbs. per square foot would not suffice to overthrow any of the vehicles.

Therefore our final conclusions are, that the average pressure must have been greater than 32 lbs. per square foot, and that there is no evidence to show that it reached 40 lbs. or 42 lbs. per square foot over the large surface exposed.

Now Leven Viaduct is in a very exposed position; and it is not reasonable to expect the same pressure on low city buildings surrounded for miles by other buildings.

The rarity of wind mishap to the large plate-glass windows of city premises is evidence of the prevalent lower pressures.

For designing purlins, I propose taking a horizontal wind pressure of 30 lbs. per square foot over large surfaces which are not in very exposed positions.

If the building be open on all four sides (*i.e.*, if the roof be supported on pillars and the wind has free escape on all four sides of the sloping surface of the roof) the wind pressure can be found by Unwin's formula embodying the results of Hutton's experiments.

If the building be enclosed on all four

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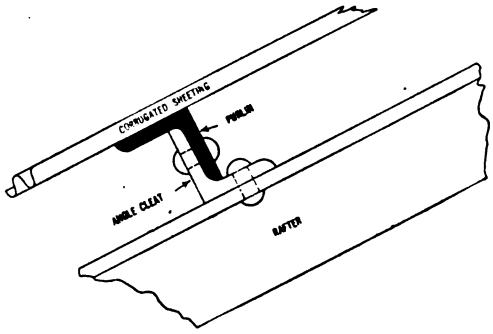

FIG. 1.—METHOD OF FIXING PURLIN TO RAFTER.

sides the wind pressure on the roof will be diminished. (*Vide* TECHNICS, No. 1, Vol. I). I do not, however, propose to make any allowance for this diminution of pressure, as I desire to obtain a rule applicable to both cases.

With horizontal wind at 30 lbs. per square foot, the pressure normal to a roof of 30° slope will be 19·8 lbs. per square foot (Unwin).

The total pressure normal to the slope of the roof will be (19·8 + 3·34) = 23·14 lbs. per square foot. (Refer to Equation 2.)

The total pressure coming on each purlin will be—

$$= W = \frac{23{\cdot}14 \text{ L.D.}}{2240} \text{ tons} \quad . \quad . \quad (3)$$

We have found the load and must now find the bending moment.

Let l = span in inches.

Let W = load on one span in tons.

For continuous girders in general it may be said—

(*a*) That the bending moments at the supports *next* to the ends are always the greatest; and are about $\frac{1}{10}$ W l.

(*b*) That they are least at the third supports from the ends, where they are about $\frac{1}{13}$ W l.

(*c*) Near the centre they are nearly uniform at about $\frac{1}{12}$ W l.

(*Vide* article on Continuous Girders in "Modern Framed Structures," by Johnson, Bryan and Turneaure.)

For continuous purlins the wind pressure on the extreme spans cannot attain its maximum value, as the air will have free escape past the gable ends. Therefore we are justified in taking the bending moment at $\frac{1}{12}$ W l throughout.

L = span in feet.

l = 12 L.

Therefore bending moment in ton-inches

$$= \frac{W l}{12} = W \text{ L ton-inches.}$$

Reference to Equation (3) will show that—

$$W L = \frac{23{\cdot}14 \text{ L}^2 \text{ D}}{2240} \text{ ton-inches} \quad . \quad (4).$$

Before we can know the moment of resistance, we must determine what working stress shall be allowed.

Now, the great factor in determining what the working stress shall be is the elastic limit of the material, rather than its ultimate strength. The elastic limit of structural mild steel is about 13·5 tons per square inch (*vide* "Official Book of British Standard Sections," publication No. 6 of Engineering Standards Committee).

There is not much fear of an ordinary purlin breaking across with the wind, because the great increase in length after the elastic limit has been passed would enable the purlin to act partially as a catenary of sufficient sag or curvature to materially reduce the stresses throughout. This fact alone would enable us to adopt somewhat higher stresses for purlins. If the stresses are kept within the elastic limit there can be no chance of undue sag.

Suppose we agree to define the maximum safe stress for purlins at $\frac{3}{4}$ of the elastic limit, *i.e.* ($\frac{3}{4}$ × 13·5) = 10·125, or (say) 10 tons per square inch.

This purlin stress may appear high, but I submit that it is the essence of good steel practice to suit the stress to the nature of the load, and to the importance of the member. The stress in a rolled steel joist embedded in the concrete base of a building need not be the same as the stress on the same section if it were used in the web of a railway lattice girder and subject to alternate tensions and compressions.

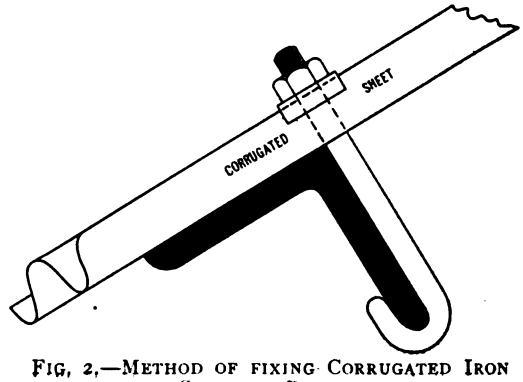

FIG. 2.—METHOD OF FIXING CORRUGATED IRON SHEET TO PURLIN.

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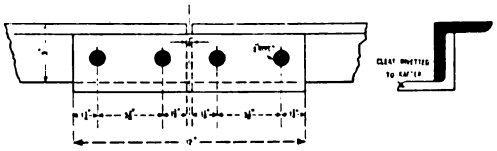

FIG. 3.—DETAILS OF JOINT BETWEEN PURLIN AND RAFTER.

The following instances of adapting stresses to structures will serve to show my meaning.

(*a*) Direct compression in mild steel pillars, from 1 ton to 6 tons per square inch, according to the length of the pillar.

(*b*) Compression flange of railway plate girders = 6 tons per square inch.

(*c*) Tension and compression for floor girders in buildings = 7 tons per square inch.

(*d*) Tension and compression for rolled steel joists entirely and thoroughly embedded in concrete floors = 9 tons per square inch.

(*e*) Working stress for angle purlins, 10 tons per square inch. (The working stresses for the roof trusses themselves should, however, be considerably below this figure.)

If this suggested stress be adopted the moment of resistance of the purlin will be Zf where Z = the section modulus in (inches)^3 and $f = (\frac{3}{4} \times 13{\cdot}5)$ tons per square inch.

Since bending moment = moment of resistance

$$\frac{23{\cdot}14\ L^2\ D}{2240} = Z\ (\tfrac{3}{4} \times 13{\cdot}5)$$

$$\therefore Z = \frac{4 \times 23{\cdot}14 \times L^2\ D}{3 \times 13{\cdot}5 \times 2240} = \frac{L^2\ D}{980},$$

or sufficiently near for practice, the requisite section modulus in (inches)^3 for angle steel purlin under a sheeted roof = Z, where

$$Z = \frac{L^2\ D}{1000};$$

here L = the span in feet, and D = the spacing of the purlins, also in feet.

Since

$$Z = \frac{L^2\ D}{1000},$$

$$D = \frac{1000 \times Z}{L^2}.$$

And

$$L = \sqrt{\frac{1000\ Z}{D}}.$$

Here are three very useful rules for almost any ordinary corrugated iron roof; for the slopes do not vary much. These rules would allow 3-in. × 3-in. × $\frac{3}{8}$-in. purlins spaced 8 ft. apart for spans up to 10 ft., or spaced 5 ft. apart for spans up to 12 ft. 9 in., or $3\frac{1}{2}$-in. × $2\frac{1}{2}$-in. × $\frac{3}{8}$-in. purlins 8 ft. apart for spans up to nearly 12 feet. It will be seen that these formulæ do not justify the long spans and wide spacing adopted on hundreds of buildings in all parts of the country, but in my opinion they give very satisfactory results, and the most practical of practical persons must admit that they give good construction. Furthermore, there is not unanimity of opinion, even among purely practical men, as to the advisability of the spans and spacing supported by Mr. Drew.

There is still one other point which we do not take into our calculations. Corrugated sheets are commonly rivetted together with staggered or zig-zag rows of rivets through the crowns or ridges of the corries. The tendency of this is to make the corrugated sheets into a sloping girder, supported at the ridges and the eaves. In addition, these sheets or hypothetical sloping girders break joint as we pass along the roof; the effect of all this is to make the roof sheets to some degrees self-supporting, and they must necessarily take some of the presumed load off the purlin.

However, a purlin theory which was founded on the assumptions that the sheets were self-supporting, and that the building was sheltered, and that the wind could not blow above a gentle breeze would soon bring the theorist into greater disrepute than ever.

The theorist and the practical man have their differences of opinion, but the really extreme points of view are those of the theorist and the keen competitive contractor. The theorist desires to take all the precautions which reason prompts; while the competitive contractor, in order to cut down the price, and so get the order, is apt to take all the risks he deems permissible. The less the responsibility the greater the amount of risk he is prepared to take. Between these two the practical man steps in; and using his judgment and his long experience, tells us what he thinks is good construction and what is bad.

By way of conclusion I would draw the reader's attention to the increased strength which can be obtained for the same expenditure of metal, by using unequal angles for purlins.

For example 3-in. × 3-in. × $\frac{3}{8}$-in. and $3\frac{1}{2}$-in. × $2\frac{1}{2}$-in. × $\frac{3}{8}$-in. angles have the same sectional area, but the moment of resistance of the latter is about 34 per cent. greater than the former.

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THE PHARMACEUTICAL INDUSTRY AND MODERN SCIENCE.

By J. R. McPHIE.

THE HISTORIC LABORATORY OF JOHN BELL AND CO., LONDON.

From an etching by Robert Macbeth, R.A.

IN the early days, chemistry was intimately associated with pharmacy; its development was contributed to in no small measure by many practitioners of the latter art, which in turn benefitted by the chemical researches of its votaries, and made progress. Unfortunately for pharmacy, this hand-in-hand development did not last long. The elder sister began to look upon the younger as precocious—as inclined to move too quickly. She began even to show some jealousy, and to look upon the rise and development of chemistry as tending to prejudice her position and profits—a fatal attitude, unfortunately not yet wholly abandoned. In this mood she built still higher the wall of mystery which wrapped her round about. and became, in the world of science, a very kingdom of China. The roads had parted. Chemistry continued to travel with accelerated velocity, pharmacy to travel more and more slowly; she was almost standing still when one day she realised that her house was in danger from quite another source than that which she had anticipated.

During her period of sloth, pharmacy's law book, the *British Pharmacopœia*, remained a conglomeration of out-of-date, inaccurate information, without order and without method, a monument to be wept over. In 1898, light appeared in the pharmaceutical firmament, in the shape of a new edition of this book. As the result of active agitation, largely among the younger pharmacists, drastic changes had been introduced. The book was fairly up-to-date in

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facts and methods. The Pharmacopœia, however, was conservative as ever, and deemed it necessary, for example, to apologise for the introduction of the word "hydroxide" in the place of hydrate. She considered whether or no her followers would be inconvenienced by the introduction of a new term. That the new term was nearer truth—was, in fact, more scientific—was not sufficient to justify its introduction. For some little time before 1898, however, firms and individuals had been on their own initiative intelligently applying chemistry and physics in the manufacture and dispensing of medicinal preparations; so that the application of modern scientific principles to the pharmaceutical industry must be dated a few years before 1898.

Pharmacy may be described as the art of identifying, preparing, analysing and dispensing medicinal substances; and the pharmacist, as one who knows the pharmacopœia. To know the pharmacopœia and carry out the above operations, the pharmacist must understand the principles of modern chemistry, physics, and botany. For the "identification" of vegetable drugs, microscopy is essential, together with a knowledge of materia medica. To use a microscope intelligently, a knowledge of the principles of optics and the theory of light must be acquired. The methods of qualitative analysis, embodying, as they do, the principles of inorganic chemistry, are requisitioned in the identification and examination of inorganic drugs. "Preparation" has passed, to a great extent, out of the hands of the retail pharmacist into those of his "manufacturing" colleague. This change has been wrought by the exigencies both of science and economics. In this department physics and engineering play a conspicuous part. In recent years great advance has been made in the machinery, both from the efficiency and from the labour- and time-saving point of view. Many laboratories are now fitted with milling machines, hydraulic presses, steam-heated evaporating pans, stills, vacuum pans, constant temperature ovens and baths, emulsifying machines, ointment machines, steam-driven mortars, mixers and sieves, pill-massing, cutting, rolling and coating machines, tablet and capsule-making machines. As an example, mills of a modern type known as root disintegrators contain a chamber in which a set of blunt blades are caused to revolve at a high speed within a circular metal grid, the root being broken up, by repeated violent impacts, into fragments the size of which is determined by the grid. Such disintegrators are usually worked by electric motors.

An innovation of the last pharmacopœia, affecting "preparation" considerably, was the recognition of the term alcohol as "generic"; the recognition of the valuable solvent properties of other alcohols besides ethyl alcohol, and of the fact that many extraction processes are effected better, or as well, by the use of ethyl alcohol of different strengths; and the institution of a gradated series of strengths for this alcohol. This necessitates an intimate knowledge of the density of liquids, and of the methods of determining the same; formerly an imperfect system of hydrometry was deemed sufficient, and a scientific knowledge of density was rarely met with.

Furthermore, the term "proof spirit" was abandoned; this term was instituted when the strength of a spirit was determined by seeing whether or no a certain amount of gunpowder exploded when the spirit was poured upon it and a light applied: it is reminiscent of the days when a beer was examined for added sugar by being poured on a wooden bench, and the wet place sat upon by a gauger in a pair of leathern breeches; difficulty in rising, on the part of the gauger, was considered to be evidence of adulteration. The principle that "the boiling point is a direct function of the pressure," is made use of in "preparation" in many ways, notably in the preparation of "extract of malt." After the ground malt has been extracted with water at a definite temperature, by maceration in a "brewer's vat," the clear extract is drawn into a vacuum pan, and the water distilled off under diminished pressure. Concentration at a low temperature is necessary, on account of the fact that diastase, the ferment of malt, is weakened in power by exposure to a temperature higher than some 63° C. The vacuum usually employed is represented by some twenty-eight inches of mercury. The preparation of chemicals, especially of organic chemicals, has of late years become an important section of pharmaceutical industry. The laboratories connected with pharmaceutical houses have taken their share in adding to the number of these compounds, and increasing existing knowledge of those already known. Acetanilide, phenacetin, and phenazone are official drugs, and, with urotropine (hexamethylenetetramine) and other compounds, are now prepared in most laboratories. Synthetic organic chemistry has entered, too, into the perfume industry, and perfumes previously produced

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only from plants are now obtained in the laboratory from coal-tar products. Progress in this direction is necessarily slow; yet, already, vanillin, coumarin (the odorous ingredient of the Tonquin bean), heliotropin, aubépine or hawthorn, ionone (artificial violet perfume), geraniol, artificial musk, artificial neroli, and others, have been prepared. In most cases the study of the natural oil has yielded some organic compound to which the odour is undoubtedly due. A study of the constitution of this body has resulted in its synthetic production. In other cases, where no knowledge of the chemistry of the natural oil exists, organic compounds have been prepared having odours more or less closely resembling the original. Heliotropin or piperonal is an interesting and instructive example. It is the methylene ether of protocatechuic aldehyde, and has been synthesised in two or three ways. In commerce, at the present time, it is manufactured from safrol by oxidation. Safrol, found in the oils of sassafras, camphor, etc., the methylene ether of allyl-dioxybenzene, is converted by the action of alcoholic alkalies into its isomer, isosafrol, containing the propenyl group. Isosafrol is oxidised by means of potassium bichromate and sulphuric acid, the mixture distilled in steam, and the distillate extracted with ether. The heliotropin so obtained is purified by the use of alkaline bisulphite. Heliotropin is a white crystalline compound having a powerful odour of heliotrope. Efforts have been made during many years to prepare quinine synthetically. Indeed, one German firm erected works for its manufacture, in anticipation of a successful method, some dozen years ago: as yet, however, the problem remains unsolved. The more thorough study of fats, it may be mentioned, and the introduction of the methods of hydrolysis by means of superheated steam and distillation in a current of steam, have been instrumental in improving the quality of glycerine and soaps. The method of distillation in steam has been introduced, too, with advantage, in the extraction of the essential oils of flowers and plants, in place of the older method of heating the herbs in water, directly by a fire.

The preparation of animal extracts is now permanent work in pharmaceutical laboratories. At first sight this looks like a "throw back" to the dark ages; yet the use and preparation of these extracts are now based on sound scientific principles. The existence of certain diseases has been traced in particular patients to the non-existence of the necessary secretions of certain glands of the human body, namely, the thyroid, thymus, supra-renal, etc. Similar glands have been taken from calves, sheep, pigs, rabbits, and other animals, and preparations of these administered with markedly successful results. Investigation has resulted in the separation of more or less "active principles" from certain of these glands: for example, "adrenaline," from the supra-renal gland and, less definitely, "thyroiodine" from the thyroid gland. Such "active principles" prove, as a rule, to be glucosides, and the method of "fractional precipitation" has often been instrumental in their separation. Of possible future changes, it is to be expected that "emulsions" will be controlled and improved by the application of the "theory of emulsions" recently advanced, together with the principles of "surface tension" and "viscosity." It is, however, in standardisation and analysis that pharmacy has made most marked progress. Some five of the tinctures of the pharmacopœia, and some half-dozen liquid extracts, must now be standardised so that they contain a specific percentage of one or more alkaloids. There exists at the present time, in the medical and pharmaceutical professions, too much prejudice in favour of tinctures containing gums, colouring and other extractive matter, and all the alkaloids of a drug—in a word, what are known as all the "virtues" of the drug—to enable solutions of one pure alkaloid to be given a fair therapeutic trial. Evidently, however, a knowledge of the therapeutic action of specific pure alkaloids is of at least as much importance as a knowledge of the therapeutic action of a mixture of two or more alkaloids, more or less impure at that. The day of standard solutions of pure alkaloidal salts must come, therefore, in the near future. The introduction of the polariscope, the method of fractional distillation, and the study of ethers, has created a revolution in the examination of essential oils in a very limited time. Adulteration had been very rife; it still exists, although to a much smaller extent than formerly. As an illustration, turpentine, the favourite adulterant for lemon oil, lowers the optical rotation of that oil. On noticing this, fractional distillation is resorted to, a study of the optical rotation of the first fraction reveals the presence of turpentine.

The historic Blaud's pill has only within very recent times been made with sufficient care and knowledge to enable the principle on which it was designed to be properly tested. It is supposed to contain one-fifth

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of its weight of ferrous carbonate; but as the inspectors have been showing recently, often did not contain any ferrous salt at all. In examining the pill, it is dissolved (if coated, after removal of the coating) in phosphoric acid, and the ferrous iron estimated by a standard solution of bichromate of potash. Phosphoric acid is used in preference to sulphuric acid, on account of the reducing action of organic matter in presence of the latter acid. The same method is applied to the examination of Blaud's capsules.

Speaking generally, the official book enacts that the majority of the drugs and preparations therein contained must pass certain specified chemical and physical tests. Melting points, boiling points, specific gravities, and optical rotations must be determined; standard volumetric solutions must be prepared, alkalimetry and acidimetry performed; metals, alkaloids, etc., must be estimated. To do these things, the operator must study the atomic theory, he must understand the methods of determining, and uses of molecular, empirical, and constitutional formulæ. He must be familiar with chemical actions and their expressions in chemical equations: in short, he must study chemistry in theory and in practice. To obtain confidence in the use of the balance, the polariscope, and the microscope, he must study physics; and if he is wise, he will go into mathematics, at all events far enough to enable him to appreciate the principle of the infinitesimal calculus, which he will find of great assistance.

Scientific principles, too, are necessary in dispensing; prescriptions, dispensed without certain precautions, give rise to the production of poisons. When chloral hydrate, potassium bromide, and an aromatic elixir are dispensed in quantities exceeding ten grains of each per drachm of the mixture, and too little alcohol is present, butyl-chloral alcoholate separates; wherein lies danger.

Recent discoveries in physics have operated indirectly on pharmaceutical industry. When X rays were discovered and their utility in surgery was noised abroad, it was to his pharmacist or pharmaceutical house that the medical man turned for information, apparatus and demonstration; in this country the pharmaceutical houses contributed in no small measure to the advance of the subject. Again, the "high frequency" treatment of phthisis, etc., called for knowledge of the principles of electricity in the industry. Later, the use of radium in cancer, etc., resulted in a demand to the trade to prepare or procure radium salts, and supply them.

SILICON STEEL FOR MAGNET CORES.

IN the course of the "James Forrest" lecture, delivered at the Institution of Civil Engineers on April 10th, 1905, Colonel Crompton said, in relation to magnet cores:—"When it became of extreme importance to minimise eddy currents, we found it necessary to mechanically subdivide our cores, either by slotting or sawing the solid castings, or by forming our magnet arms of thin wrought-iron plates, held in position by being cast into cast-iron or cast-steel yokes. But at this stage we encountered an annoying difficulty, which still exists, and has been the cause of much disappointment and loss to steel-founders and dynamo-builders. I refer to the difficulty in producing steel castings for magnets, yokes, and frames sufficiently free from blow-holes or porosity to ensure that the magnet-core portions are of equal density, and, therefore, of sufficiently equal magnetic moment. . . . This difficulty is a real one, and may possibly be met by further development of Barrett's discovery, that the addition of silicon in suitable proportions to cast-iron renders the whole very fusible, so that complicated and difficult castings free from porosity can be made from it; but, in addition, he has shown that we obtain reduced hysteresis. It is probable that the silicon acts by reducing the combined carbon in the iron to the form of carbide, so that the pure iron is left with a structural formation calculated to give high permeability, as it will be in the form of a sponge or network, which will give great freedom for molecular movement; moreover, at first sight we might think that such pure iron would have the disadvantage of reducing resistivity, which would facilitate the formation of eddy currents; yet, in practice, this is not so, as although the iron has lessened resistivity, the cross-section of the filaments of the pure iron sponge are small, and, therefore, the mass as a whole has considerable resistance to these eddy currents. Barrett's discoveries, therefore, point in the direction from which we may hope to obtain considerable improvement in our magnet cores."

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THE EVOLUTION OF THE MACHINE WOOL COMB.

PART I.

By ALDRED F. BARKER, Professor of Textile Industries,
The City of Bradford Technical College.

IN the last article the life and inventions of Dr. Cartwright were dealt with. This article will lead directly into the Factory System, with the personalities of Donisthorpe, Heilmann, Lister, the Holdens, Noble, and others standing boldly out as pioneers of machine wool combing.

It will be well to consider briefly the state in which Dr. Cartwright left wool combing. His first comb consisted of a large vertical cylinder with combs placed round the circumference (Fig. 1). This was the idea worked upon by Heilmann, and is, at present, the basis of all cotton combs. His second comb (Fig. 2), known in all its forms as "Big Ben," had, as a main feature, a large circular comb placed horizontally with a smaller circular clearing comb; thus most of the motions were circular. It is interesting to note that the latest development in wool combs—the Noble—is based on circular motion, while the lashing-on motion of the Cartwright comb was adopted in the square motion comb. If the engineer's standard of a machine is adopted, *viz.*, that every motion must be circular, it must be admitted that Cartwright approached this ideal in a wonderful manner, considering that he, as other inventors had previously and have since done, would naturally tend to imitate the movements of the hand process. Unfortunately, he adopted the horizontal position of the pin—just as in the fixed hand comb—with a circular motion to obtain continuity of work; and it was left to a later inventor to adopt the vertical position—the only position which could be satisfactory on a circular foundation.

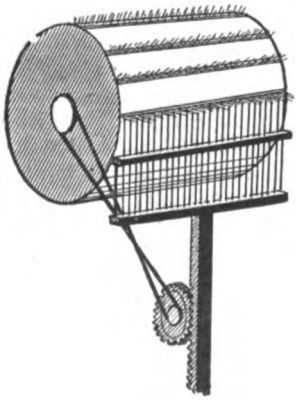

FIG. 1.—DR. CARTWRIGHT'S FIRST COMB.

INTERMEDIATE STAGE BETWEEN CARTWRIGHT AND HEILMANN.

Prior to 1840 Messrs. William Toplis, John Hawksley (who used hot air), Wright, John Passman, Anthony Amatt (who employed separate machines for filling, combing, and drawing off), James Noble, Donisthorpe, Rawson and Collier, aided in an evolution which was to culminate on the one hand in the Heilmann comb, and on the other hand in the Lister and square motion combs. It seems as though the Collier machine (stated in the *Histoire Documentaire de l'Industrie de Mulhouse* to be the invention of a man named Godard, of Amiens) was the only comb that achieved anything like practical success, all the other combs requiring too much attention, and further, damaging the wool which they combed.

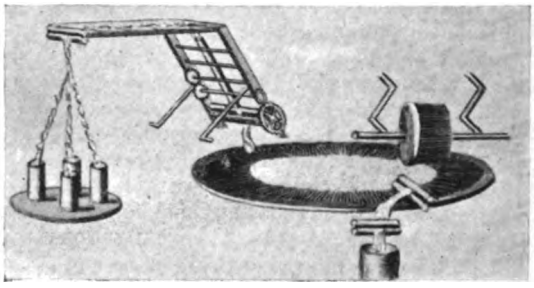

FIG. 2.—DR. CARTWRIGHT'S SECOND COMB.

PLATT AND COLLIER'S MACHINE.

The latest form of the Collier comb, known under the title of Platt and Collier (Fig. 3), consisted of two circles practically representing two hand combs. One circle was charged with the wool to be combed, then the combing operation commenced—the empty comb robbing the full comb, this being a gradual operation, the circles being slowly moved within one another's sphere of action. Finally drawing off from both circles, just as in drawing off from the two hand combs, was accomplished. The circles were heated by steam.

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The objections to this comb were that in the first place it was an intermittent machine, and, consequently, could not compete with a continuous machine; but more important still, the wool was undoubtedly broken, and thus a large amount of noil produced, while the straightening of the long fibres to form the "top" was not at all satisfactory.

George Edward Donisthorpe.

George Edward Donisthorpe was born in 1810, at Market Bosworth; in 1835 he was associated with Henry Rawson in wool combing; in 1836 he came to Yorkshire, and in 1842 brought out improvements on the Collier machine. In 1842-3 Mr. Donisthorpe became associated with Lord Masham (then Samuel Cunliffe Lister), and together they practically extinguished hand-combing in this country. If tradition be right, he was later associated with Noble in the bringing out of the most useful machine on the market, *viz.*, that known by the name of the "Noble" comb. He died at Harrogate on January 13th, 1875. There is no doubt that Donisthorpe was a master mind in reference to this subject, but as Burnley says, in his work on "Wool Combing," "He was too much engrossed in the work of invention to avail himself to the full of the benefit to be derived from that work." What he would have done without the more practical mind of Lord Masham can well be imagined by the fate which overtook Dr. Cartwright and others.

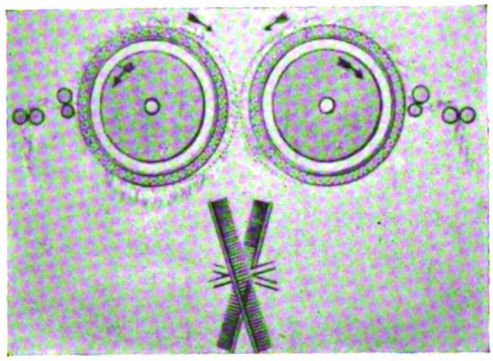

Fig. 3.—Platt and Collier's Comb.

Josué Heilmann.

One of the most important figures in the evolution of the machine wool comb now appears upon the scene, *viz.*, Josué Heilmann. To do justice to his memory would require at least much more space than can possibly be given here.

The following particulars are taken from the *Bulletin de la Société Industrielle de Mulhouse*, the only remaining copy of which has been most kindly placed in the hands of the writer by the secretary of this society:—

"On December the 27th, 1848, Henri Thierry Koechlin read the obituary notice on Heilmann before an assembly of the society. He said: 'In recapitulating the titles that Josué Heilmann has acquired in our esteem, and in our affection, we recall the numerous difficulties which have had to vanquish the men engaged at the same time as he in the industry; and those which have succeeded in the career will appreciate most justly the efforts made by our colleague to advance the science of the industry; they will see these are their pioneers, who for them have cleared the route now so easy, and they will esteem at their real value the genius and the perseverance which have been necessary to bring to a useful end the creations which, looking back, may appear of small importance.'"

Heilmann was born in 1796, and his education was directed to fit him for becoming a merchant. His tastes for the manual and mechanical arts were pronounced at a very early age, his companions admiring the productions of his precocious genius. He left the paternal house in 1801, and entered the Institute Pestolozzi at Yberdon. One day he heard a professor say to his students, "One will never attain anything great in this world if one continually demands, 'How much will it bring me in?'" These words made a great impression upon him, and he acted up to them throughout his life. To his great pleasure, in 1816 his parents decided to commence a small hand-spinning cotton factory. To learn this industry he was placed in the factory of MM. Tissot and Rey, where he at once felt at home. He worked hard, and further became a student at the Conservatoire des Arts et Métiers, studying physics and mechanics. In 1817 he returned to Mulhouse, where he took charge of the technical part of the concern of Vieux Thann. Not being able to produce sufficient material from his machines, Heilmann, at the age of twenty-two, fitted up a factory of 10,000 spindles, drawing up the plans and particulars and details; this factory was opened in 1819. In 1820 he married the daughter of Monsieur Jacques Koechlin; in 1823 he began to study power loom weaving, and invented the pulley and groove eccentric for commanding the healds. In 1826 he commenced improvements in preparing

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machines for cotton; and aided, by his wife, he invented what is now known as the "put-through" embroidery machine, which obtained for him the gold medal and decoration of the Legion of Honour in 1834. In 1830 he constructed a vertical loom and a roller temple; this temple being probably the original of the present roller temple. In 1833 he invented a measuring and folding machine, and in 1834 attempted to construct a spinning machine with flexible flyer. In 1835 he devoted himself to silk weaving, and had in hand some 240 power looms. About this time he brought out a system of transmitting power by iron ropes. In 1841 he took out French and English patents for weaving at the same time two pieces of velvet superimposed and cut by the middle. In 1843 he commenced his study of cotton combing—apparently starting from the Collier machine—and eventually applied his ideas to wool, waste silk and hemp combing. He died on November 5th, 1848, at the age of fifty-three years. The notice concludes in these words:—"Through a series of researches made by him in the name of your Committee he has made many questions clear, and has further given a sane and impartial judgment on the documents which to you have been submitted."

Lord Masham.

Mr. S. C. Lister appears to have been attracted to wool combing at a very early age. Thus early realising the prize which would go to the man who first practically succeeded in combing wool by machinery, he approached Mr. Donisthorpe, and in conjunction with him, in 1843, succeeded in combing fine Botany wool. There is still extant an order given about this date for fifty machines of his construction. There is no doubt that he it was who dealt the death-blow to hand combing, and finally placed the worsted industry on the basis which has resulted in our latter-day prosperity. Although having achieved success, he was not satisfied with the Cartwright-Donisthorpe machine, and thus was led to develop both the "square motion" and the "nip" combs. With a square motion comb he undoubtedly dealt the blow to the hand-combing industry, but the latter comb he evidently deemed the more practical, and although obliged to purchase the previous nip patent of Heilmann to carry out his ideas to their ultimate issue, he hesitated not a moment, but went straight for the goal which so many had previously failed to reach.

His success is so well known as to require no further treatment here. In the *Journal of the Society of Arts*, for July 2nd, 1886, the following notice appears:—

"The Albert Medal for the present year was (with the approval of the President, H.R.H. the Prince of Wales) awarded by the Council to Mr. Samuel Cunliffe Lister 'for the services he has rendered to the textile industries, especially by the substitution of mechanical wool-combing, and by the introduction and development of a new industry—the utilisation of waste silk.'

"The Council have been enabled to recognise for the first time services rendered to the textile manufactures, by making this award to one who may fairly be said to have done more than any other man of the present generation to promote the advance of this most important branch of British commerce.

"Though the inventions of Mr. Lister are well known to all textile manufacturers, it may yet be interesting to place them briefly on record here:—In 1847 he was engaged in introducing a wool-combing machine into England and France for fine wool. In 1850 he, jointly with the late Mr. Donisthorpe, invented the only wool-combing machine which could comb all kinds of wool. So important was this invention, that, although the cost of a single machine was only some £300 or £400, it commanded a royalty of £1000. After years of opposition, Mr. Lister's fellow-townsmen of Bradford have acknowledged him as a public benefactor, and have erected a statue to him in their Town Hall (Fig. 4). He embarked the whole of the fortune realised by wool-combing, in the utilisation of silk waste, that is, the waste and refuse made in winding silk from the cocoons. He invented machines for combing this waste silk and making it up into yarn; and then—and this was, perhaps, the most important of all his achievements—he introduced and perfected velvet looms, by which velvets are now produced in this country by machinery. This has, for the second time, given a new industry to the country, and to Bradford in particular. Mr. Lister's works at Manningham, for the utilisation of this previously waste material, cover eleven acres, and are the largest in the kingdom, not excluding those of the late Sir Titus Salt; they give employment to some 4,000 workmen. The annual value of the exports of velvet from these works is reckoned in hundreds of thousands of pounds, which is all created out of what is called even to this day, 'silk waste.'"

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Sir Isaac Holden.

Sir Isaac Holden was born on May 7th, 1807, near Glasgow. The educational advantages which Scotland then offered its rising generation no doubt explain to the full the success which attended Sir Isaac's career. In 1828 he came to Leeds, and about this time discovered the lucifer match. In 1833 he, like Heilmann, started from the Collier wool comb, working in conjunction with Mr. Robert Townend, of Cullingworth. From the first his inclinations seem to have run in favour of the square motion. He became associated with Mr. S. C. Lister in 1847, and after 1848 spent most of his time in France at the factory they were then conjointly starting at St. Denis. Working in a country where the Lister Nip was excluded through the prevailing Heilmann Nip patents, and further, having distinct feelings towards the square motion comb, it was but natural that he should endeavour to develop this mechanism. Possibly the nature of the material — fine short Botany wool—which he had to comb also urged him in this direction. Thus it may be said that had it not been for the foregoing influences, it is very unlikely that the square motion comb, with all its details as existing to-day, would have been developed.

As with Lord Masham, there is no need to refer further to the success which followed his endeavours. The partnership with Lord Masham was severed and, as previously intimated, Lord Masham turning his attention to other equally important textile developments, left the field for the further development of the square motion comb free to the Holdens.

Fig. 4.—Statue of Lord Masham.
Erected in the grounds of the Town Hall, Bradford.

James Noble.

James Noble has already been mentioned as taking out a patent (in 1805); 28 years later, and in the following years, he took out further patents, and in 1853 became associated with Donisthorpe. Noble probably received most of his instruction from Donisthorpe, while the success which has attended the Noble comb must also be largely attributed to the admirable workmanship which Messrs. Taylor, Wordsworth and Company have, from the first, put into the machine. It did attain to a practical success about the sixties, and to-day, through a change in circles and other adjustments fitting it for combing long, medium, or short wool, it is the comb most largely adopted in the trade.

PARTICULARS OF MEDALS AWARDED TO DR. CARTWRIGHT.

(Copied from the actual medals now in possession of the Bradford Corporation.)

SILVER MEDAL.
The Rev. E. Cartwright.
Arts and Commerce Promoted.
For his Three-Furrowed Plough.
MDCCCIII. (1803).

GOLD MEDAL.
The Rev. E. Cartwright, D.D.
Board of Agriculture.
Voted Feby. 12, 1805.

SILVER MEDAL.
To The Rev. Dr. Edmd. Cartwright.
Board of Agriculture.
Voted May 6, 1806.

GOLD MEDAL.
To The Rev. E. Cartwright, D.D.
Arts and Commerce Promoted.
For a Traversing Apparatus.
MDCCCXVI. (1816).

GOLD MEDAL.
To The Rev. E. Cartwright, D.D.
For Comparative Experiments on Manure.
MDCCCXVIII. (1818).

SILVER MEDAL.
To The Rev. E. Cartwright, D.D.
Board of Agriculture.
For Essay on the Means of Employing the Poor.

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CUTTING, GRINDING, AND MOUNTING ROCK SECTIONS.

By E. HOWARD ADYE.

II.—Mounting Sections in Canada Balsam.

CRUDE Canada balsam of commerce is much too viscid and apt to be charged with impurities to be suitable for mounting sections. Its use in this form is beset by countless troubles and annoyances, including the difficulty of avoiding air-bubbles, and the impossibility of making the medium set hard so as to hold the section. Some authorities recommend baking the mounted preparation; but such a procedure is inadmissible, save in exceptional instances.

Obviously therefore, the Canada balsam must be specially prepared for microscopical work. Properly prepared balsam may be purchased from some dealers, but the author has found it far more satisfactory to make his own medium, and strongly advises others to do likewise. The following is his method, which may be relied upon to give uniformly good results: — Purchase, from some thoroughly trustworthy source,* a sufficient quantity of the best commercial Canada balsam, — say about a quarter of a pound. Immerse about two-thirds of the unstoppered bottle containing the balsam in a bath of water, and bring the latter to a boil. By this time the balsam will have become sufficiently mobile to be poured without waste into an evaporating basin. The most useful patterns of water-bath and evaporating basin are depicted in Figs. 1 and 2. Place the evaporating basin upon the water-bath, after having removed the required number of rings from the latter, and continue to boil the water so as to permit the uncovered balsam to harden *very gradually* as it loses its volatile constituents: this process may take a few or many hours, according to the quality and condition of the balsam. Some workers may be tempted to expedite matters by heating the basin of balsam directly over a Bunsen flame or other source of heat; but, apart from the liability to an explosion, through ignition of the highly inflammable vapours given off by the balsam, the latter can scarcely fail to be discoloured by charring. By the gentler methods of the water-bath, sand-bath, or hot-air chamber the balsam will finally grow quite hard, when allowed to get cold, without appreciable alteration of its colour— a pale honey-yellow. During the process of hardening, samples should be tested from time to time, by removing a drop or two, at the end of a glass dipping-rod. The drop may be allowed to fall on to a piece of paper, and immediately thereafter touched by the finger-end. If sufficiently hardened, the particle ought not to remain sticky; it should be capable of being rolled between the fingers into a hard yet tough mass, without being brittle. In the latter event, the hardening has been overdone, and more fresh balsam should accordingly be added to the basin-contents. It is essential that the balsam shall be hardened to a nicety,—neither under nor overdone; and when this has been accomplished, the balsam may be poured out upon a cold glass or other plate, and rolled into sticks for future use.

Fig. 1.—Copper Water-Bath, with Removable Rings

Fig. 2.—Enamelled Iron Evaporating-Basin.

The hardened balsam-sticks, when broken to pieces, ought next to be placed in a glass-stoppered bottle, and covered with sufficient rectified benzol to yield a fairly mobile solution, about the consistency of an ordinary syrup. This solution must be very carefully filtered to render it suitable for microscopic slide-mounting; and to that end a hot-water funnel (Fig. 3) will be required. This contrivance consists of a glass funnel, encased in a metal jacket arranged to hold water. The water can thus be heated to any desired degree by means of a Bunsen ring clamped to a stand, as shown in Fig. 3. To filter the balsam, a circular sheet of Schleicher and Schull's Rhenish filtering paper, folded into a

* Messrs. Townson and Mercer, of 34, Camomile Street, London, E.C.; or Messrs. Baird and Tatlock, 14, Cross Street, Hatton Garden, London, E.C.

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FIG. 3.—HOT-WATER FUNNEL.

FIG. 4.—CANADA BALSAM BOTTLE.

cone, should be wetted with a little benzol and placed in the funnel. The required quantity of balsam solution may then be poured in, and the gas circle very gently turned on, cautiously ignited, and kept low, to prevent an explosion;—for it must be constantly borne in mind that both benzol and balsam are highly inflammable. The filtrate should be collected and kept in a special unstoppered, but glass-capped bottle (*see* Fig. 4), provided with a dipping-rod.

Canada balsam thus prepared will be found the best and most generally useful of media for mounting not only rock and kindred sections, but a vast variety of permanent microscopic objects. The solvent used may be varied by a substitution of ether, chloroform or xylol for the benzol; but the benzol will be found not only the best, but the cheapest and most trustworthy for ordinary technical operations. Then again, the Canada balsam itself may be replaced by other gums, such as dammar and storax for particular preparations; but Canada balsam holds its premier position on the score of all-round utility, by reason of its comparatively low refractive index, which averages approximately 1·540. Operators should endeavour to determine for themselves the refractive indices of the various media and reagents used in microscopical work. They will find most of these given in the text-books on Physics, and in some of the best treatises on Microscopy; and, by consulting such works and experimenting for themselves, they will come to the conclusion that balsam, dissolved in benzol as directed above, is without doubt the best medium for rock-section mounting, as well as for the mounting of the majority of stained and hardened animal and vegetable cells and tissues. It is important to appreciate the optical phenomena due to differences in the refractive indices of objects under examination. For example, when a thin slice of quartz, which has a *mean* refractive index approximating to that of Canada balsam, is mounted in that medium, its contours and surfaces are almost if not quite invisible in ordinary light, but the inclusions with which it usually abounds are mapped out with great clearness, and can therefore be studied to advantage. On the other hand, when a crystal of olivine is similarly mounted, its moderately high index of refraction, averaging about 1·68, reveals fairly bold outlines, and characteristically roughened surfaces; while a minute crystal of zircon, which has a very high mean index, is rendered conspicuous by its dark boundaries.

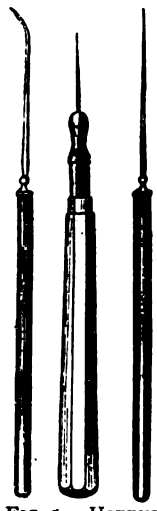

FIG. 5.—USEFUL FORMS OF MOUNTED NEEDLES.

The technical methods to be followed in mounting objects in balsam have not been recorded in any of the current text-books, and are indeed, only known and practised by a few of the leading expert slide-mounters of to-day. They necessitate the strict observance of a general routine to ensure invariably successful results, and may be considered seriatim as follows:—(I.) Cleaning the slips and cover-glasses. (II.) Placing the prepared sections or other objects in benzoled balsam in the dust-proof cabinet. (III.) Mounting the preparations in their proper positions on the slips. (IV.) Cleansing, sealing, and labelling the finished slides.

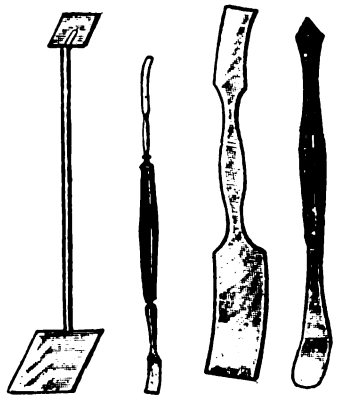

FIG. 6.—USEFUL FORMS OF SECTION-LIFTERS, MADE BY MESSRS. BAIRD AND TATLOCK.

For the present, it will suffice to explain the methods indicated above by reverting to

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the hard rock sections left lying thoroughly freed from cement and other impurities in an artist's saucer-palette containing clean methylated spirit. These sections should be carefully removed (by means of a mounted needle, fine camel's-hair or sable brush, or one of the many forms of section-lifters sold by dealers in microscopes and their accessories), and transferred to another saucer-palette or watchglass filled with pure benzol, and kept covered therein, until wanted for mounting. It is necessary to drain off all methylated spirit from the section before transferring it to the benzol, as these two

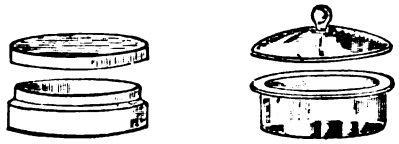

FIG. 7.—USEFUL FORMS OF COVERED GLASS BASINS FOR CLEANING SLIPS AND COVER-GLASSES.

liquids are not easily miscible, and any adherent drops of methylated spirit, however minute, may at first mar the beauty of the mounted preparation, although they will gradually become absorbed and disappear. To drain off superfluous spirit from the section on the lifter, or when poised on the edge of a mounted needle or brush, the tip of a finger, or edge of a snip of blotting-paper, may be cautiously applied.

Microscope slips are supplied in the standard sizes of 3 inches by 1 inch, and 3 inches by 1½ inch for extra large objects. The former are most generally used. The edges should be smooth and the surfaces flat and free from blemishes. It is most satisfactory to use the best quality of extra thin white glass slips, guaranteed to be of uniform thickness. These are sold at five shillings per gross, and do not usually require to be specially cleaned. With regard to cover glasses, it is most satisfactory to use the best quality of extra thin No. 1 circles, which are usually supplied in standard sizes of ⅝, ¾, ⅞, 1 and 1¼ inches in diameter, at about five shillings per ounce. The best cover-glasses, like the best microscope glass-slips, seldom need to be specially cleaned; but, as instances sometimes arise where any amount of ordinary rubbing with damp and afterwards with dry silk cannot remove a faint-blue cloudy film from the surfaces of slips and covers, it is advisable to get into the way of cleaning them. Then again, slips and cover-glasses that have been used and discarded, on account of a spoiled or faulty preparation, can be used over again, after being thoroughly cleaned by the following simple plan. Place the slips into one, and the cover-glasses into another covered glass basin (4 inches in diameter by 2 inches deep is a convenient size), and pour in sufficient strong sulphuric acid to just immerse the glasses within; cover the basins, and allow them to stand aside for at least a couple of hours. Drain away the acid and wash the contents of the basins under a running water-tap for a minute or two. Drain away the water, and pour in enough methylated spirit to cover the glass-slips and cover-glasses. After remaining for two or three hours in the spirit, the glass slips may be removed, wiped dry with a linen cloth, and stored for immediate or future use. They ought to be *brilliantly* clean. The cover-glasses require tender handling by reason of their fragile nature. They should be removed from the spirit, and placed separately, one by one, on the special india-rubber draining mat shown by Fig. 8. When quite dry the cover-glasses should be gathered together, wrapped in tissue-paper, and replaced within their original cardboard boxes.

Immediately before use, the cover-glasses should be finally re-cleaned. The old-fashioned clumsy way of doing this is, unfortunately, still taught by most text-book writers, and is in vogue at many of our university and college laboratories. By it, students are directed to take up the delicate cover-glass with an old silk pocket-handkerchief and rub both surfaces simultaneously

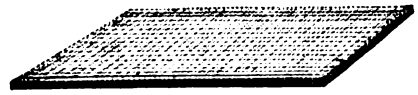

FIG. 8.—INDIARUBBER MAT FOR DRAINING COVER-GLASSES.

between the thumb and finger. There can be no doubt that, by prolonged practice, the operator may acquire dexterity sufficient to save the majority of the cover-glasses from an untimely fate; but, in the face of other far simpler and surer methods, the plan cannot be recommended. A better method for minimising waste through breakages is to use the buff-leather pads, sold for that purpose by dealers; but even these would be unhesitatingly discarded when it is known that, for a trifling outlay, one can provide himself with the main requisite for cleaning cover-glasses to perfection, without fear of breaking any save defective glasses. All that is needed is to purchase a small cutting, say six or twelve

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inches square, of American oil-cloth from any draper, and to lay this down, face-upwards, by one's side upon the operating table; a better plan would be to buy a small cutting of the very finest oil-cloth, preferably of a dark colour, from some upholsterer, and to fix this flat, in place of paper, upon one of Messrs. George Rowney's framed drawing boards with shifting panel. The method of finally cleaning the cover-glasses, without risk of breakages, is simplicity itself. Place as many of the cover-glasses as are required for immediate use (say, half-a-dozen at a time) on the surface of the oil-cloth. Breathe gently upon them, and with the forefinger guarded by a piece of old silk pocket-handkerchief, press upon and rub the glasses thoroughly clean. The glasses will adhere evenly to the perfectly flat oil-cloth, and considerable pressure may be exerted without the slightest fear of breakage. Indeed, the silk rag may be rubbed swiftly to and fro, over the surfaces of the whole six glasses, with impunity. Now, insert the blunted point of a penknife between the cover-glass and oil-cloth, and turn the former over. The oil-cloth will give way readily to the gentle pressure thus exerted, so that the six cover-glasses can be rapidly turned, and their reverse faces similarly rubbed till quite clean. These last cleaned faces are to be used for mounting the sections or other objects upon; and the cover-glasses, when removed from the cleaning board, should be placed slant wise against a rest—the edge of a saucer palette—so that any particles of dust from the air may not touch or cling to the surface upon which the object is to be mounted.

(*To be continued.*)

REVIEWS.

Modern Theory of Physical Phenomena: Radio-activity, Ions, Electrons. By Augusto Righi, Professor of Physics, University of Bologna. Authorised translation by Augustus Trowbridge. pp. 165, with 17 line diagrams. (New York: The Macmillan Co., 1904). Price 5*s*. net.

This charming little book is the translation of a chapter added to a work by the author, entitled, "Telegrafia senza Filo" (telegraphy without wires). It gives, in a simple and unpretentious manner, an account of modern theories of the connections between electricity and matter, and should prove very welcome to those readers who wish to obtain a general acquaintance with this subject without going deeply into quantitative investigations. The book includes seven chapters respectively devoted to electrolytic ions and electrons; electrons and the phenomena of light; nature of the kathode rays; the ions in gases and solids; radio-activity; mass, velocity, and electric charge of ions and electrons; electrons and the constitution of matter. A useful bibliography is appended.

Practical Methods of Electro-Chemistry. By F. Mollwo Perkin, Ph.D., Head of the Chemistry Department, Borough Polytechnic, London. pp. xiii. + 322, with frontispiece (a portrait of Faraday) and 64 illustrations in the text. (London: Longmans, Green and Co., 1905). Price 6*s*. net.

During recent times the importance of electrolytic methods, whether for the analysis or preparation of substances in the laboratory or or commercial production on a large scale, has steadily increased. The book before us deals only with electrolytic methods on the laboratory scale; it is divided into three parts, each part being subdivided into chapters. The first part deals generally with electrical phenomena so far as these are of importance in electrolytic investigations, and includes a description of the various instruments and accessories used. The second part is devoted to electro-chemical analysis, and gives a good account of the quantitative separation and determination of the metals. The third part deals with electrolytic preparation of compounds, including the reduction and oxidation of organic compounds. An appendix deals with the preparation of reagents and the use of logarithms, and includes tables of five-figure logarithms. An index has been added. The book is well written, and the printing and illustrations leave nothing to be desired.

Telegraphy. By Sir W. H. Preece, K.C.B., F.R.S., formerly Engineer-in-Chief and Electrician, Post Office Telegraphs; and **Sir J. Sivewright, M.A., K.C.M.G.** Eighteenth impression. pp. xiii. + 504, with 272 diagrams. (London: Longmans, Green and Co., 1905). Price 7*s*. 6*d*. net.

This well-known book has been thoroughly brought up to date by the authors, and includes descriptions of the most modern devices used in telegraphy, such as fast-speed recorders, automatic translating apparatus for submarine circuits, Murray's improvements in the Wheat-

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stone automatic apparatus, and the new telegraph switching system. The paper insulated telephone cable is discussed at length. A chapter on wireless telegraphy, considered both from its theoretical and practical aspects, has been added, and will be found very interesting. An appendix includes the specification of the Engineering Standards Committee for copper conductors.

The Sewage Problem: A review of the evidence collected by the Royal Commission on Sewage Disposal. By Arthur J. Martin, A.M.Inst.C.E., M.R.San.I. pp. xvi. + 363. (London: The Sanitary Publishing Co., Ltd., 1905). Price 8*s.* 6*d.* net.

The Royal Commission on Sewage Disposal was appointed on May 7th, 1898; since that date it has examined many witnesses, visited numerous sewage disposal works, and instituted various scientific investigations. Four reports have been issued, and the work of the Commission is not yet completed. For those actively interested in the problem of sewage disposal, the reports mentioned above contain much information of the highest value, but this information is somewhat hard to arrive at, data respecting any particular problem or difficulty being scattered over 821 pages. Mr. A. J. Martin has, therefore, performed a most useful service in digesting the information contained in the reports, and compressing it into readable compass. The various chapters treat of the purification of sewage on land; purification of sewage in artificial works; chemical precipitation; bacterial disposal of sewage; the need of preliminary treatment; preliminary bacterial processes; comparative values of modes of preliminary treatment; final treatment; bacterial filters; contact beds; flow filters; filtering material; contact beds *v.* trickling filters; filters *v.* land; other aspects of the problem; supplementary reports on land treatment, etc.; and the outlook. Mr. Martin's work has been carefully and conscientiously performed, and we cordially congratulate him on carrying through an arduous task, which is sure to prove of great service.

Tools for Engineers and Woodworkers; including Modern Instruments of Measurement, by Joseph Horner, A.M.I.Mech.E. pp. xii. + 340, with 456 illustrations. (London: Crosby Lockwood and Son, 1905). Price 9*s.* net.

Mr. Horner enjoys a well-earned reputation for ability as a writer on engineering subjects, and in writing the book before us he appeals to a wide public which has shown keen appreciation of his former works. For the most part, hand tools only are dealt with, although a chapter is devoted to lathe tools for metal turning. Throughout the book the various aspects of the subject are considered from the point of view rather of the user than of the designer of tools; every tool in common use is described and illustrated. Strictly speaking, measuring instruments are not tools; but the author has done well to include their description in this book, since in all cases accurate work with tools must be preceded by accurate measurements with instruments of precision. The numerous line drawings used to illustrate the text are well executed, and the writing and printing leave nothing to be desired.

A Manual of Quaternions, by Charles Jasper Joly, M.A., D.Sc., F.R.S., Sec. R.I.A., Royal Astronomer of Ireland. pp. xxvii. + 320. (London: Macmillan and Co., Limited, 1905). Price 10*s.* net.

The beautiful system of quaternion analysis invented by Sir William Rowan Hamilton has scarcely acquired the popularity which might reasonably have been predicted for it; this is perhaps due to the fact that Hamilton was a metaphysician, and in order to establish some of the fundamental properties of quaternions, he used trains of reasoning which would hardly appeal to the ordinary mathematical or physical student. Tait's book on quaternions also presented many difficulties, even to accomplished mathematicians; and, besides Hamilton's and Tait's works, the literature of the subject is chiefly confined to a few scattered papers published in the proceedings of the various learned societies. Dr. Joly's book will be welcomed by mathematical students, both because the properties of quaternions are deduced by methods presenting no avoidable difficulties, and also because numerous examples which will serve to test the reader's knowledge of the subject have been added. A vector is simply a directed quantity, or a line possessing both magnitude and direction. The cardinal functions of two vectors α and β are $S\alpha\beta$ and $V\alpha\beta$. The expression $-S\alpha\beta$ is the product of one vector into the projection of the other upon it; and $V\alpha\beta$ denotes a vector perpendicular to both α and β, containing as many units of length as there are units of area in the parallelogram of which α and β form conterminous sides. The product of the vector α into the vector β is taken as

$$\alpha\beta = S\alpha\beta + V\alpha\beta.$$

This is a *quaternion—i.e.*, the sum of a scalor and a vector.

The properties of quaternions are deduced by Dr. Joly in the first twenty pages of his book; the remainder of the treatise is devoted to the applications of quaternion analysis to geometrical and physical problems; plane and spherical trigonometry, the geometry of the straight line, plane, and sphere, differentiation, linear and vector functions, quadric surfaces, geometry of curves and surfaces, statics, finite displacements, strain, dynamics, the operator ∇, projective geometry, and hyperspace are treated in successive chapters. The electromagnetic theory is dealt with in a very interesting manner in Chapter XVI. We are rather surprised by the note on p. 211, in which it is stated that no satisfactory name has been proposed for the operator ∇; we have always understood that Hamilton proposed the name *nabla*—the Arabic name for a harp—for this operator. Finally, we may confidently recommend Dr. Joly's book to those readers who wish to become acquainted with, or extend their knowledge of the fascinating subject of quaternion analysis.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the* 10*th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

SYNTHESIS OF PROTEIDS.—What is the nature of the experiments which have been performed to synthesise proteid matter?

When proteid matter is acted on by dilute acids, it yields a very considerable proportion of compounds belonging to the class known as amino-acids: for example, aminoacetic acid or "glycine" $NH_2 \cdot CH_2 \cdot CO_2H$; aminophenylpropionic acid $C_6H_5 \cdot CH_2 \cdot CH(NH_2)CO_2H$; aminosuccinic acid or "aspartic acid"

$$CO_2H \cdot CH_2 \cdot CH(NH_2) \cdot CO_2H,$$

and others.

In the past, the efforts of chemists have been confined mainly to attempts to prepare condensation products from the simple amino-acids of known constitution. Such products were obtained from aspartic acid a quarter of a century ago, and indefinite compounds, having many of the characters of proteid substances, were prepared by Schutzenberger ten years later, his method consisting in removing the elements of water from mixtures of amino-acids and urea by the aid of phosphorus pentoxide.

In 1894, an amorphous material, which had nearly the same ultimate composition as gelatine, was obtained by Lilienfeld from the ethyl ester of aminoacetic acid by the use of powerful reducing agents. These experiments, although no doubt very suggestive, threw little new light on the question of the exact structure of the proteids, and gave what were almost certainly mixtures, and did not lead to the isolation of any substances which could be recognised as individuals.

Curtius and, after him, Fischer, have worked out methods by means of which it is possible for chemists to synthesise, step by step, "condensed" amino-acids in a pure state and having known constitutions. One of the first of these was discovered by Curtius in 1881, and was obtained by the action of benzoyl chloride on the silver salt of aminoacetic acid; it contained the benzoyl group and two aminoacetic acid residues, and was therefore a benzoyl derivative of the simplest possible "dipeptide"

$$[C_6H_5 \cdot CO] \cdot [NH \cdot CH_2 \cdot CO] \cdot [NH \cdot CH_2 \cdot CO_2H].$$

Curtius also obtained from ethyl aminoacetate an anhydride of aminoacetic acid; this was found, later, to be an internal anhydride of the simplest possible dipeptide, and had the constitution

$$\begin{matrix} NH \cdot CH_2 \cdot CO \\ \dot{C}O \cdot CH_2 \cdot \dot{N}H \end{matrix}$$

and from it, by the action of acids, Fischer finally succeeded in obtaining the dipeptide itself

$$NH_2 \cdot CH_2 \cdot CO \cdot NH \cdot CH_2 \cdot CO_2H.$$

The higher peptides may now be obtained from the lower ones if suitable steps are taken. Thus, if $NH_2 \cdot X \cdot CO_2H$ and $NH_2 \cdot Y \cdot CO_2H$ be supposed to represent two peptides from which it is proposed to produce the higher condensed peptide $NH_2 \cdot X \cdot CO \cdot NH \cdot Y \cdot CO_2H$, the first of these may be converted into its "carboxyethyl" derivative $CO_2C_2H_5 \cdot NH \cdot X \cdot CO_2H$ by the action of ethyl chlorocarbonate $Cl \cdot CO_2C_2H_5$, a step which is necessary in order to render the contained amino-group incapable of taking part in the subsequent condensation. The resulting compound is then converted into an ester and condensed with the ester of the other peptide, when the following reaction occurs:

$$CO_2C_2H_5 \cdot NH \cdot X \cdot CO_2C_2H_5 + NH_2 \cdot Y \cdot CO_2C_2H_5 = CO_2C_2H_5 \cdot NH \cdot X \cdot CO \cdot NH \cdot Y \cdot CO_2C_2H_5 + C_2H_5 \cdot OH,$$

and a simple derivative of the desired "polypeptide" is obtained.

Still later, more convenient methods have been worked out by Fischer. Thus a halogen-substituted acid chloride may be made to interact with an amino-acid, *e.g.*,

$$Cl \cdot CH_2 \cdot CH_2 \cdot CO \cdot Cl + NH_2 \cdot CH_2 \cdot CO_2H = HCl + Cl \cdot CH_2 \cdot CO \cdot NH \cdot CH_2 \cdot CO_2H;$$

the resulting halogen compound affords the corresponding amino-compound—the "polypeptide"—by simple treatment with ammonia

$$2NH_3 + Cl \cdot CH_2 \cdot CO \cdot NH \cdot CH_2 \cdot CO_2H = NH_4Cl + NH_2 \cdot CH_2 \cdot CO \cdot NH \cdot CH_2 \cdot CO_2H.$$

Great strides in other directions, too, have been taken, but it is impossible here to go into further details.

ELECTRONS.—A sphere of radius a is charged with q electro-magnetic units of electricity, and is set in motion with a velocity v. Find the increase in the inertia of the sphere due to its electric charge.

On p. 423 it is proved that the inertia of a single tube of force extending from the surface of the sphere to a distance very great in comparison with a is equal to

$$\frac{\kappa q \sin^4 \theta}{4\pi a}$$

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where θ is the angle that the axis of the tube makes with the direction of motion of the sphere. From the centre of the sphere describe two imaginary cones, of which the generating lines respectively make angles of $\left(\theta + \frac{d\theta}{2}\right)$ and $\left(\theta - \frac{d\theta}{2}\right)$ with the axis (see p. 422); these cones cut off from the surface of the sphere a circular strip of breadth $ad\theta$, and length $2\pi a \sin\theta$, so that the area of the strip is equal to $2\pi a^2 \sin\theta d\theta$. The total number of tubes of force leaving the charge q is equal to $4\pi q/\kappa$, and therefore the number of tubes leaving unit area is equal to

$$\frac{4\pi q}{\kappa} \div 4\pi a^2 = \frac{q}{\kappa a^2}.$$

Hence the number of tubes leaving the strip mentioned above is equal to

$$2\pi a^2 \sin\theta d\theta \times \frac{q}{\kappa a^2} = \frac{2\pi q}{\kappa} \sin\theta d\theta,$$

and the inertia of these tubes is equal to

$$\frac{\kappa q \sin^2\theta}{4\pi a} \times \frac{2\pi q}{\kappa} \sin\theta d\theta = \frac{q^2}{2a} \sin^3\theta d\theta,$$

and the inertia of all the tubes leaving one-half of the sphere between a pole and the equatorial section is equal to

$$\frac{q^2}{2a}\int_0^{\frac{\pi}{2}} \sin^3\theta d\theta = \frac{q^2}{2a}\int_0^{\frac{\pi}{2}} (1 - \cos^2\theta) \sin\theta d\theta$$

$$= \frac{q^2}{2a} \cdot \Big[-\cos\theta + \frac{\cos^3\theta}{3} \Big]_0^{\frac{\pi}{2}} = \frac{q^2}{3a}.$$

Hence the inertia of all the tubes of force leaving the sphere is equal to $(2q^2)/(3a)$, the result obtained by Professor J. J. Thomson.

CENTRIFUGAL PUMP.—A centrifugal pump delivers 1500 gallons per minute. Fan, 16 inches diameter. Lift, 25 feet. Inclination of vanes at outer periphery to the tangent, 30°. Find the breadth at the outer periphery, that the velocity of whirl may be reduced one-half, and also the revolutions per minute, assuming gross lift 1½ times the actual lift.—*Cotterill's Applied Mechanics, p.* 538.

If Fig. 1 is regarded as representing a fixed pipe through which water is caused to flow in a jet delivering W lbs. of water per second at a velocity of V feet per second in the direction

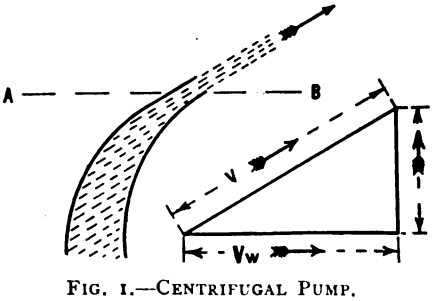

FIG. 1.—CENTRIFUGAL PUMP.

shown, then, representing the component of V in the direction of AB by V_W, $\frac{WV_W}{g}$ units of momentum per second have been given to the water in the direction AB. This will cause a reaction of P lbs. in the direction BA, and

$$P = \frac{WV_W}{g}$$

because change of momentum per second is equal to force.

If, instead of a fixed pipe, the water issues from the fan of a centrifugal pump, as in Fig. 2, with a velocity *relative to the fan* which is represented by V_R, then we may find the absolute velocity of the water (V_A) by adding to V_R the tangential velocity of the wheel V_T.

Resolving V_A parallel and at right angles to the tangent to the wheel, we obtain V_W, which represents the velocity of whirl of the water, and which is in the same direction as the motion of the wheel.

If, then, W lbs. of water per second issue from the fan, $\frac{WV_W}{g}$ units of momentum per second are generated in the direction of the tangent to

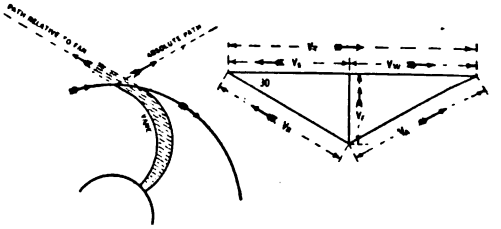

FIG. 2.—CENTRIFUGAL PUMP.

the wheel, which will cause a reaction of P lbs., tending to retard the movement of the wheel, and $P = \frac{WV_W}{g}$.

Since the velocity of the fan rim is V_T feet per second, therefore the retarding force is overcome through V_T feet per second, and the work done in turning the fan = $P \times V_T$ ft.-lbs. per second,

$= \frac{WV_W}{g} \times V_T$ ft.-lbs. per second.

According to the data given, the velocity of whirl of the water is to be half the tangential velocity of the fan rim, or $V_W = \frac{V_T}{2}$.

Hence the work done per second in turning the fan $= \frac{WV_T}{2g} \times V_T = \frac{WV_T^2}{2g}$.

But the amount of work done in pumping can be determined from other considerations, for to raise 1500 gallons of water virtually through $1\frac{1}{2} \times 25$ feet will require

$$\frac{15,000}{60} \times 1\tfrac{1}{2} \times 25 = 9375 \text{ ft.-lbs. per second.}$$

Hence $\frac{WV_T^2}{2g} = 9375$,

and therefore $V_T = \sqrt{\frac{9375 \times 2g}{W}}$.

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$$W = \frac{15{,}000}{60} = 250 \text{ lbs. per second, hence}$$

$$V_T = 49 \text{ feet per second.}$$

If the diameter of the fan is represented by D, and the number of revolutions per minute by N,

$$\pi D N = 60\, V_T;$$

$$\text{therefore } N = \frac{60\, V_T}{\pi D} = \frac{60 \times 49}{3{\cdot}14 \times 1{\cdot}33} = 700.$$

Let V_S denote the tangential velocity of the water relative to the wheel.

In order to find V_S, we may suppose the wheel to be brought to rest by adding to its tangential velocity V_T an equal velocity in the opposite direction, *viz.*, $-V_T$. If $-V_T$ be also added to the water, the relative velocities are not affected. Hence $V_S = V_W - V_T$.

As the water issues from the fan it has a velocity along the vane (represented by V_R), which is the resultant of V_S and the radial velocity V_F.

Since the direction of V_R is inclined at 30° to that of V_S, and V_S in the present case equals $\frac{V_T}{2}$ in magnitude, then $V_F = \frac{V_T}{2} \tan 30°$.

Since $V_T = 49$ feet per second, and tan 30° = ·577, then $V_F = 14$ feet per second.

If the width of the fan at the outer periphery is represented by w, then the area of issue of the water $= \pi D w$, and if Q = number of cubic feet discharged per second, $Q = \pi D w V_F$.

Hence $w = \frac{Q}{\pi D V_F}$, and since $Q = \frac{250}{62{\cdot}5} = 4$ cubic feet, then $w = \frac{4}{3{\cdot}14 \times 1{\cdot}33 \times 14}$

$= 0{\cdot}068$ feet

or 0·81 inches.

CONIC SECTIONS.—Why is it that, whereas in Euclid the *converses* of propositions are proved at length, in Geometrical Conics they are invariably stated without any proof whatever? Is there any *à priori* reason for this apparent omission?

How would you demonstrate the following:—

"If we have any two fixed straight lines OA, OB, and if from a point Q the line QV be drawn parallel to OB to meet OA in V; then, if Q move in such a manner that QV^2 varies as OV, the point Q will describe a parabola, of which OA is a diameter, and OB the tangent at the extremity of that diameter."—(*C. Smith, p.* 54).

The omission of the proof of the converse proposition does not depend on any profound general principle, but must be regarded as an idiosyncrasy of the author of the book. It would be natural, however, for him to assume that when a student has reached the stage of studying geometrical conics, he (the student) probably possesses sufficient intelligence to supply the proof for himself. Whether the assumption is in all cases well founded is not for us to say.

The rider set is a direct consequence of the proposition established on page 54 of "Smith's Geometrical Conics," *viz.*, that the square of the ordinate of any diameter is in a constant ratio to the intersept of the diameter. If inquirer will substitute the line OA for PK, and the line OB for PV in the figure given there, he will no doubt be able to complete the solution.

EQUATION.—Solve the equation

$$\tan(\pi \cot\theta) = \cot(\pi \tan\theta).$$

Since

$$\tan A - \cot B = -\frac{\cos(A+B)}{\cos A \sin B},$$

the given equation can be thrown into the form

$$\tan(\pi\cot\theta) - \cot(\pi\tan\theta) = -\frac{\cos\{\pi(\tan\theta + \cot\theta)\}}{\cos(\pi\cot\theta)\sin(\pi\tan\theta)} = 0.$$

Since the quantity in the denominator can never be equal to infinity, we may discard it, and solve the equation

$$\cos\{\pi(\tan\theta + \cot\theta)\} = 0.$$

For this to be true,

$$\pi(\tan\theta + \cot\theta) = \frac{2n+1}{2}\pi,$$

where n is an integer, positive or negative,

$$\therefore \pi \frac{2}{\sin 2\theta} = \frac{2n+1}{2}\pi,$$

or

$$\sin 2\theta = \frac{4}{2n+1}.$$

Since a sine cannot have a value greater than unity, the values of n are limited to 2, 3, 4, 5, ... and − 3, − 4, − 5, . . . which give the following values of θ:—

$n = 2$, $\sin 2\theta = 0{\cdot}8$, $2\theta = 54°$ (nearly), $\theta = 27°$.
$n = 3$, $\sin 2\theta = 0{\cdot}571$, $2\theta = 35°$ (nearly), $\theta = 17{\cdot}5°$.
$n = 4$, $\sin 2\theta = 0{\cdot}444$, $2\theta = 26°$ (nearly), $\theta = 13°$, etc., etc.

$n = -3$, $\sin 2\theta = -0{\cdot}8$, $2\theta = -54°$ (nearly), $\theta = -27°$,

$n = -4$, $\sin 2\theta = -0{\cdot}571$, $2\theta = -35°$ (nearly), $\theta = -17{\cdot}5°$, etc., etc.

Since the original equation still holds good if we substitute $(n\pi \pm \theta)$ for θ, where n is any integer, the remaining roots of the equation can be found by substituting the values of θ already found in the expression $(n \times 180 \pm \theta)°$.

MECHANICS.—A pulley block is suspended from a peg by a loop of cord passing round it, of such length that the straight portions next the peg make angles α with the vertical. The block is divided along a vertical diameter into two halves, which rest against each other. Show that when the weight of the block and the load suspended from it is W, the two halves of the block are pressed together with a force

$$\tfrac{1}{2}W(\sec\alpha + \tan\alpha).$$

—*London University, Inter. B.Sc.*, 1899.

Let T be the tension of the cord; then, resolving the forces acting on the peg vertically, we have

$$2T\cos\alpha = W;$$

$$\therefore \quad T = (W \sec\alpha)/2.$$

The tension must have the same value in all

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parts of the cord. The horizontal forces acting on one half of the block are: (1) The pressure P between it and the other half of the block. (2) The tension T acting horizontally at the lower end of the division between the blocks. (3) The horizontal component of the tension T of the string where it leaves the block; since at this point T is inclined at an angle $\left(\frac{\pi}{2} - \theta\right)$ to the horizontal, the required horizontal component is T sin θ. Hence, for equilibrium

$$P = T + T \sin\theta = \frac{W}{2}(\sec a + \tan a).$$

THEORY OF EQUATIONS.—If

$$x + y + z + u = 0,$$
$$ax^2 + by^2 + cz^2 + du^2 = 0,$$
$$\frac{1}{x(a^2 - e^2)} + \frac{1}{y(b^2 - e^2)} + \frac{1}{z(c^2 - e^2)} + \frac{1}{u(d^2 - e^2)} = 0,$$

where $e^2 = -\dfrac{abc + bcd + cda + abd}{a + b + c + d}$,

prove that

$$x^n\{(a+e)^n - (a-e)^n\} + y^n\{(b+e)^n - (b-e)^n\} + z^n\{(c+e)^n - (c-e)^n\} + u^n\{(d+e)^n - (d-e)^n\} = 0.$$

—*Royal University of Ireland, 1st Exam. in Honours*, 1903.

The expressions

$$\{1 - x\theta(a-e)\}\{1 - y\theta(b-e)\} \times \{1 - z\theta(c-e)\}\{1 - u\theta(d-e)\}$$

and

$$\{1 - x\theta(a+e)\}\{1 - y\theta(b+e)\} \times \{1 - z\theta(c+e)\}\{1 - u\theta(d+e)\}$$

will be equal for all values of θ, provided

$$\Sigma x(a-e) = \Sigma x(a+e) \quad . \quad . \quad . \quad (1)$$
$$\Sigma xy(a-e)(b-e) = \Sigma xy(a+e)(b+e) \quad . \quad (2)$$
$$\Sigma xyz(a-e)(b-e)(c-e) = \Sigma xyz(a+e)(b+e)(c+e) \quad . \quad . \quad (3)$$

and

$$(a-e)(b-e)(c-e)(d-e) = (a+e)(b+e)(c+e)(d+e) \quad . \quad (4)$$

(1) gives $\Sigma x = x + y + z + u = 0$ . . . (5)

(2) gives $\Sigma xy(a+b) = 0$, or $\Sigma ax^2 - \Sigma ax \Sigma x = 0$.

Hence, from (5),

$$\Sigma ax^2 = ax^2 + by^2 + cz^2 + du^2 = 0 \quad . \quad (6)$$

(4) gives $e^2 + \dfrac{abc + abd + acd + bcd}{a + b + c + d} = 0$. (7)

Dividing the left-hand side of (3) by

$$xyzu(a-e)(b-e)(c-e)(d-e),$$

and the right-hand side by the equal quantity

$$xyzu(a+e)(b+e)(c+e)(d+e),$$

we obtain

$$\Sigma \frac{1}{x(a-e)} = \Sigma \frac{1}{x(a+e)},$$

or

$$\Sigma \frac{1}{x(a^2 - e^2)} = \frac{1}{x(a^2 - e^2)} + \frac{1}{y(b^2 - e^2)} + \frac{1}{z(c^2 - e^2)} + \frac{1}{u(d^2 - e^2)} = 0 \quad . \quad . \quad (8)$$

Hence, if (5), (6), (7), and (8) hold, we obtain

$$\frac{\{1 - x\theta(a-e)\}\{1 - y\theta(b-e)\}}{\{1 - x\theta(a+e)\}\{1 - y\theta(b+e)\}} \times \frac{\{1 - z\theta(c-e)\}\{1 - u\theta(d-e)\}}{\{1 - z\theta(c+e)\}\{1 - u\theta(d+e)\}} = 1.$$

Thus the logarithm of this quantity is equal to zero, for all values of θ. Expanding each factor in the form

$$\log_e(1 - t) = -\Sigma_1^{\infty} \frac{t^n}{n},$$

and equating the coefficient of θ^n to zero, we obtain the required result.

INTEGRATION.—Prove that the areas of the two loops of the curve

$$r^2 - 2ar\cos\theta - 8ar + 9a^2 = 0$$

are $(32\pi + 24\sqrt{3})a^2$ **and** $(16\pi - 24\sqrt{3})a^2$.

—(*Edwards' Integral Calculus, p.* 182.)

The graph of the equation is not difficult to draw; it will be found to consist of two oval curves, having $\theta = \pi$, $r = 3a$ as a common point, and one oval lying entirely within the other. Also the initial line is an axis of symmetry. From the theory of quadratics we have, if r_1 and r_2 denote the two values of r to any value θ

$$r_1 + r_2 = 2a(4 + \cos\theta),$$
$$r_1 r_2 = 9a^2.$$

Hence

$$r_1^2 + r_2^2 + 2r_1r_2 = 4a^2(16 + 8\cos\theta + \cos^2\theta)$$

r_1 refers to the larger oval, and its area is given by $A_1 = \int_0^{2\pi} r_1^2 d\theta$.

Similarly $A_2 = \int_0^{\pi} r_2^2 d\theta$.

Hence

$$A_1 + A_2 + 2\int_0^{\pi} r_1 r_2 d\theta = 4a^2 \int_0^{\pi} \left(16 + 8\cos\theta + \frac{1 + \cos 2\theta}{2}\right) d\theta;$$

$$\therefore A_1 + A_2 + 18a^2\pi = 4a^2(16 + \tfrac{1}{2})\pi;$$

$$\therefore A_1 + A_2 = 48\pi a^2.$$

Again

$$(r_1 - r_2)^2 = 4a^2(7 + 8\cos\theta + \cos^2\theta) = 4a^2\left(16\cos^2\frac{\theta}{2} - 4\sin^2\frac{\theta}{2}\cos^2\frac{\theta}{2}\right) = 16a^2\left(4 - \sin^2\frac{\theta}{2}\right)\cos^2\frac{\theta}{2},$$

and remembering that $r_1 > r_2$

$$r_1 - r_2 = 4a\cos\frac{\theta}{2}\sqrt{\left(4 - \sin^2\frac{\theta}{2}\right)}$$

and $r_1 + r_2 = 2a\left(5 - 2\sin^2\frac{\theta}{2}\right)$;

$$\therefore r_1^2 - r_2^2 = 8a^2\left(5 - 2\sin^2\frac{\theta}{2}\right)\sqrt{\left(4 - \sin^2\frac{\theta}{2}\right)}\cos\frac{\theta}{2}$$

and $A_1 - A_2 = \int_0^{\pi} (r_1^2 - r_2^2) d\theta$.

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Let $\sin \frac{\theta}{2} = 2 \sin \phi$.

When $\theta = 0$, $\phi = 0$, and when $\theta = \pi$, $\sin \phi = \frac{1}{2}$ and $\phi = \frac{\pi}{6}$.

We have then

$$A_1 - A_2 = 64a^2 \int_0^{\frac{\pi}{6}} (5 - 8 \sin^2 \phi) \cos^2 \phi d\phi$$

$$= 64a^2 \int_0^{\frac{\pi}{6}} \{\tfrac{5}{2}(1 + \cos 2\phi) - (1 - \cos 4\phi)\} d\phi$$

$$= 64a^2 \left\{\frac{3}{2} \cdot \frac{\pi}{6} + \frac{5}{4} \sin \frac{\pi}{3} + \frac{1}{4} \sin \frac{2\pi}{3}\right\}$$

$$A_1 - A_2 = a^2(16\pi + 48\sqrt{3}).$$

Also $A_1 + A_2 = 48\pi a^2$.

Hence $A_1 = (32\pi + 24\sqrt{3})a^2$

and $A_2 = (16\pi - 24\sqrt{3})a^2$.

GEOMETRY.—In a given circle inscribe an isosceles triangle, whose equal sides produced if necessary shall pass through two given points.

The problem does not admit of a purely Euclidian solution.

Looked at analytically, the problem is as follows:—Find the locus of a point such that the line joining it to a fixed point always bisects the angle between the lines joining it to two other given fixed points, and determine the points of intersection of the locus and a circle having the first fixed point as centre.

By taking the first fixed point O as origin, and the axis of x through the mid-point of the line joining the other two given points A and B, the equation to the locus is in its simplest form, *viz.*:

$$a(x^2 + y^2)y = (x^2 - y^2)hk - xy(a^2 - h^2 + k^2),$$

Where a is the distance of O from the mid-point of AB, and $(a + h, k)$, $(a - h, k)$ the co-ordinates of A and B.

The equation is a cubic having the origin as a double point, A and B are points on the curve, and the curve has infinite branches.

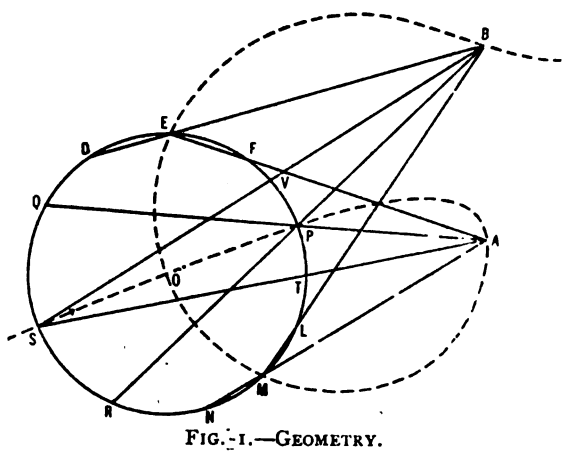

FIG. 1.—GEOMETRY.

The locus is, however, most easily drawn from geometrical considerations, *viz.*, it must be the locus of the intersections of tangents drawn from A and B to all the circles having the given point O as centre.

The subjoined sketch was constructed as above, and gives a notion of the kind of locus for points O, A, B, relatively situated as shown.

The locus being drawn, the isosceles triangles are easily constructed by joining the points of intersection of given circle to the points A and B.

From the figure, it is evident that if radius of circle be less than the smaller of OA and OB, four isosceles triangles DEF, LMN, PQR, VST are possible. If the radius is greater than this, two triangles (never less) are possible.

In the special case in which A and B are situated symmetrically with regard to O, the locus consists of a circle and a straight line, as can be seen from the equation and from the graphical construction. For this a purely Euclidian construction is easily made.

The infinite branches of the locus are asymptotic to a straight line whose equation can be found by ordinary algebraic means.

GEARING.—Please inform me how to design and generate the teeth on bevel gears which are helical or "scroll," instead of radial. Also what advantage have such pairs of bevels over ordinary ones?

If it were required to design a mechanism which would correctly form the teeth of ordinary straight-toothed bevel wheels, then such an arrangement as is shown in Fig. 1 would answer this purpose. The line AB represents the axis of a fixed spindle upon which the bevel wheel is rigidly attached. At the end B of the spindle is a socket in which a pin can revolve, but is not free to move along the axis AB. The projecting end of the pin is forked and a transverse pin CD passes through eyes in the fork and connects a cranked bar EB to the forked spindle. The cranked bar is square in section and carries a tool holder F which may be slid along the straight part of the crank. The tool is so shaped and fixed that the tool-point always moves along the axis EB. The end E of the bar EB is cut away to allow the centre line of the bar EB to pass through some point in the contour of a fixed former plate or template GH. By moving the point of contact between the bar and the template completely down one curved edge of the template, the face and flank of one side of the wheel tooth will be generated by the axis EB. If then the bar be fixed with the point of contact in the highest possible position and the tool-holder slid along the bar, the tool point will trace a line in the working surface of the tooth. Withdrawing the tool, shifting the point of contact a little lower, and again causing the tool-holder to traverse the bar, will give a second line, and this cycle of operations may be repeated until the complete surface has been generated. By turning the tool box and the contact finger round, the other side of the tooth may be formed in a similar manner. If a dividing plate is

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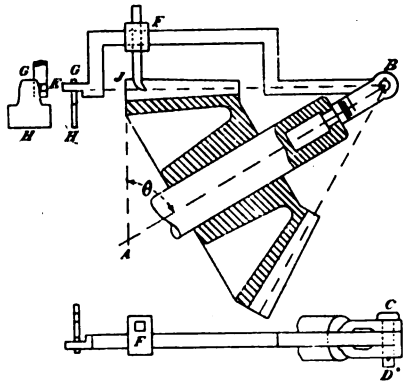

FIG. 1.—GEARING.

attached to the fixed spindle AB successive teeth may be formed. It should be noted that in all positions the axis EB passed through the fixed point B in the axis AB.

Suppose now it were required to modify the mechanism in order to obtain a helical, instead of a straight tooth, then it would be necessary to cause the tool to move along the bar at a perfectly uniform speed, and simultaneously cause the wheel to turn round the axis AB with a uniform angular velocity. At the same moment that the tool point has completed half its traverse the angular motion of the wheel must be reversed in direction, and continue at the same rate as previously until the end of the cut.

It is not suggested that this mechanism should actually be applied to shape helical wheel teeth, although machines for cutting straight teeth on bevel wheels are made on the principle first described, but the conception of the mechanism will enable the form of helical bevel wheel teeth to be understood.

The actual construction of these wheels is generally carried out by means of a moulding machine, and for this purpose a tooth block which consists essentially of a model of a pair of teeth is needed.

Owing to the difficulty of generating their rather complicated shape, these models are rarely constructed with a high degree of accuracy. If carefully carried out, the following method will result in a very close approximation to a perfectly formed tooth.

In Fig. 2 (*a*) and (*b*) a tooth block is shown upon which two straight teeth of a bevel wheel are formed. It is assumed that the principles of formation of these teeth, as also that of the template GH in Fig. 1, are already understood. If not, the necessary information may be gained from a text-book of machine drawing, such as that by Messrs. Bevis and Low. Assuming definite data for these teeth, such as their length, contour, pitch, and pitch circle diameter, let it be required to produce teeth similar in all respects except that the required teeth are to be of helical form. Referring to Fig. 1, the line JA may be regarded as the centre line of the end of a tooth produced to meet AB, the axis of the wheel. If numerous lines parallel to JA are drawn to meet AB in a similar fashion, and all are revolved about AB in such a way as to keep the angle F constant, then each tooth will be divided into a large number of slightly curved slices. If these slices are indefinitely thin, all of them, except the ones at each end, may be displaced in a manner which will result in the same form as if they were produced by the mechanism described.

In the actual model this may be approximated to as follows. Instead of cutting each tooth out of a single piece of material, let a number of parallel slices be prepared as in Fig. 2 (*a*), one joint being exactly midway along the tooth. The shapes of the ends are set out (but with a modification to be afterwards described), and the ruled surfaces of a straight tooth formed. The slices are then separated, each one is given the necessary displacement, and all are firmly cemented to each other and to the foundation block. Strictly, the joints between the sections should be curved, but in most cases a very small error will be introduced by making them plane. At this stage the various sections produce a coarsely stepped tooth with the actual section required at the commencement of each step. If now the projecting parts of the tooth are smoothed off, so that the known accurate sections are joined by a smooth curved surface, then the desired form will be attained.

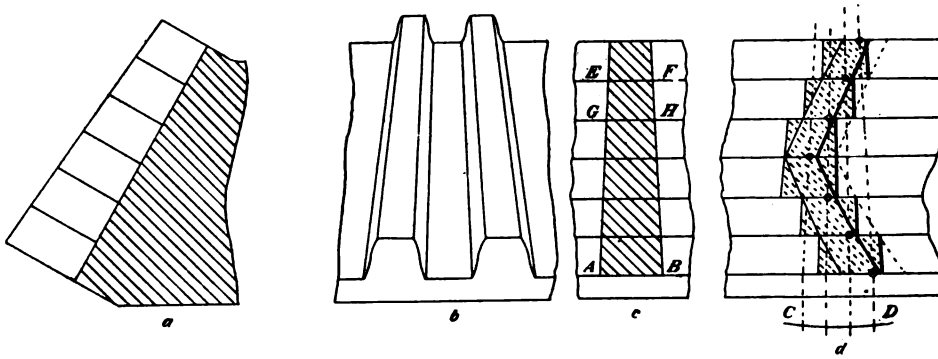

FIG. 2.—GEARING.

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In Fig. 2 (*c*) the shaded area is a projection of the space on the tooth block which is covered by the tooth, so that a horizontal line across this space at any part gives the width of the base of the tooth at that place. In Fig. 2 (*d*) the arc CD may be regarded as a plan of the line AB. Then if the tooth is divided into six sections as shown, the distance CD, which is the amount of rake given to the tooth (referred to the maximum diameter of the wheel), is set off and divided into three equal arcs, that is, just half the number of sections. From the division points lines are drawn across the tooth block surface to the apex of the pitch cone. Horizontal lines drawn upon the block give the intersections of the joints of the sections with the block surface. The small circles show the successive positions of the joint centres of each intersection, and the lengths of the successive lines of intersection, such as EF, GH, may then be transferred to the diagram (*d*). If from the ends of these lines, lines are now drawn to the apex of the pitch cone, the shaded area in diagram (*d*) shows the final positions of the tooth sections.

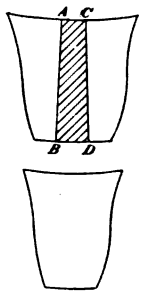

FIG. 3. GEARING.

By drawing smooth curves through the re-entering angles of the shaded figure it becomes evident that if the original straight tooth were made with correct lateral dimensions, then the finished tooth will, after cutting away the projecting parts, be far too small in its lateral dimensions. The error will decrease as the number of sections is greater, diminishing to O when the number is infinite. Hence the modification in making the straight tooth which was previously referred to. This is shown in Fig. 3, which represents the large end of a tooth. AC is made equal to one of the small arcs along CD in Fig. 2 (*d*) and the lines AB, CD radiate from a centre corresponding to the point A in Fig. 1. The shaded part will then compensate for the smoothing off of the projecting parts.

The rake given to the tooth should be rather more than the pitch, in order that when the tooth is in gear there will always be two points of contact between pairs of teeth in the plane which contains the axes of the shafts. This will ensure the wheels answering the purpose for which the helical form is adopted, *viz.*: the reduction to a minimum of noise and vibration in running.

It is important to note when a pair of these wheels are made to gear together, that if the large part of the tooth on one wheel is made with a right-hand twist, then the large part of the tooth on the other wheel must have a left-hand twist. Hence a pair of mitre wheels cannot be moulded from the same tooth models, as is the case with straight teeth.

BEAM.—A plank twenty-four feet long, and of uniform cross section, is floating in still water. It carries two weights, each of 56 lbs., at six feet from either end. Draw diagrams of shearing force and bending moment on the plank. Read off the maximum values of these quantities.—*Board of Education, Practical Plane and Solid Geometry, Stage III.*, 1904.

Since the plank is of uniform section and is symmetrically loaded, every point in the lower surface is submerged to the same depth, and therefore the hydrostatic pressure is uniformly distributed over that surface. The forces keeping the plank in equilibrium are then as shown in Fig. 1, the sum of the upward pressures being equal to the sum of the two weights. The upward pressure to which each foot of length of the plank is subjected may be denoted by w.

In order to obtain a more typical case than the given data afford, Figs. 1, 2, and 3 are drawn with the weights nearer to the ends than is stated, but equidistant from the centre of the beam and equal to each other.

Referring to Fig. 2, let R be the resultant pressure upon that part of the plank lying between one of the weights and the end of the plank, and let a denote half the distance between the two weights. Since the downward forces equal the total upward pressure, each weight may be expressed as $R + wa$.

Taking any section, such as CD, between E and O (O being the centre of the plank), we may, by considering the forces acting on the left of the section, express the bending moment at CD as

$$w(a-y) \times \frac{a-y}{2} - wa(a-y) + Rb.$$

A bending moment is to be considered positive if it tends to rotate the part on the left of the section relatively to the part on the right of the section in a clockwise direction. The third term does not vary for any section within the limits of the points E and F, since it expresses a couple.

The above expression may be re-stated as

$$\frac{w}{2}(a-y)^2 - wa^2 + way + Rb.$$

If now $(a-y)^2$ is expanded, and the terms of the complete expression summed up, we shall obtain

$$\text{Bending moment at CD} = \frac{w}{2}y^2 - \frac{w}{2}a^2 + Rb.$$

The second term on the right-hand side is constant, as well as the third, since neither w nor a varies.

In Fig. 3, let AB be a datum line whose length represents that of the plank, and let the length of the vertical intercept between AB and the curved line represent to scale the bending moment at the section through which it is drawn.

Then, measuring positive quantities in an upward, and negative quantities in a downward direction, M represents the bending moment at CD, and, being below the datum line, it must be negative. The curved line is clearly due to the variable term $\frac{w}{2}y^2$, and, since $\frac{w}{2}$ is constant, it must be a parabola, with O as vertex, and ON as axis.

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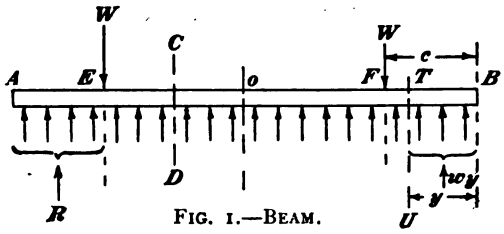

FIG. 1.—BEAM.

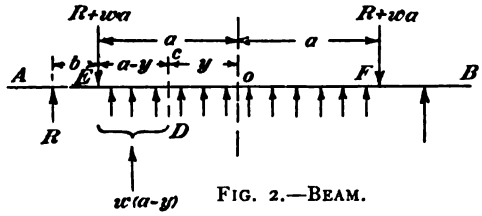

FIG. 2.—BEAM.

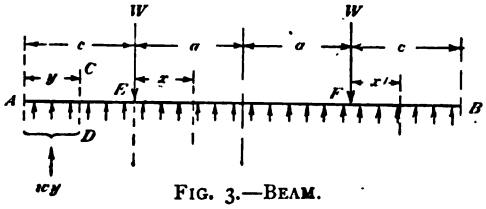

FIG. 3.—BEAM.

At the centre of the plank $y = 0$, and the value of the term $\frac{wy^2}{2}$ is therefore 0.

At the point E (Fig. 2) $y = a$, and therefore $\frac{w}{2}y^2 = \frac{w}{2}a^2$, from which we obtain the point P in the curve.

If a section be considered, such as TU in Fig. 1, which does not lie between the two weights, then, referring to the same figure, the bending moment may be expressed as

$$wy \times \frac{y}{2} = \frac{w}{2}y^2.$$

Hence the curved line QB in Fig. 3 is also a parabola, having B as vertex, and RB as axis, and, when $y = c$, $\frac{w}{2}y^2 = Rb$ (for $c = 2b$, and $R = wc$). At the end of the beam $y = 0$, and therefore $\frac{w}{2}y^2 = 0$.

Hence the points Q and B in Fig. 3 are determined.

The numerical values of $\frac{w}{2}a^2$ and Rb being found and set off to scale as in Fig. 3, the curves may be drawn geometrically, as shown in Fig. 4.

The distances OS and SP are each divided into the same number of equal parts. At each dividing point in OS, a vertical line is drawn, and from each dividing point in SP a line is drawn to O. Taking the order of the points from O to S and from S to P, the intersection of the lines proceeding from corresponding points will give a point in the curve, for if in Fig. 5 n represents the number of parts in each line, and the intersection of the lines drawn from the mth point in each series is considered, we have

$$\frac{VU}{\frac{m}{n} \times PS} = \frac{y^1}{y}, \text{ and as } PS = ky^2$$

$$VU = \frac{y^1}{y} \times \frac{m}{n} ky^2.$$

But $\frac{m}{n} = \frac{y^1}{y}$, and therefore

$$VU = \frac{y^1}{y} \times \frac{y^1}{y} ky^2 = k(y^1)^2,$$

which proves that V is a point in the parabola.

So far, the problem has been treated generally, symmetrical loading only being assumed, but in working out the particular case which is stated we get $w = 4\frac{2}{3}$ lbs., $a = 6$ ft., $R = 6 \times 4\frac{2}{3}$ lbs., and $b = 3$ ft. From these data $\frac{w}{2}a^2 = 84$ lb.-ft., and $Rb = 84$ lb.-ft. Since, then, $\frac{w}{2}a^2 = Rb$ for the particular case, the actual diagram will

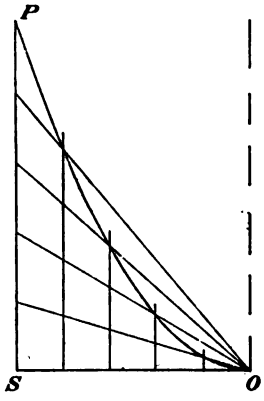

FIG. 4.—BEAM.

have the form given in Fig. 6, from which we see at once that the maximum bending moment is 84 lb.-ft., and that it occurs at the two sections through which the vertical centre lines of the weights pass.

Shearing force is considered to be positive, if the resultant force acting upon the part on the left of the section regarded tends to cause that part to rise relatively to the part on the right of the section.

At any section between A and E in Fig. 7, such as that at CD, the shearing force—which may be denoted by S—will have the value $w \times y$, and since w is constant, the curve of shearing force for this part is a straight line. At the end of the plank $y = 0$, and therefore $S = 0$. Taking the section on the left of E, but indefinitely near to it, $y = c$, and $S = w \times c$.

At the section on the right of E, but indefinitely near to it, $S = wc - W$. At any

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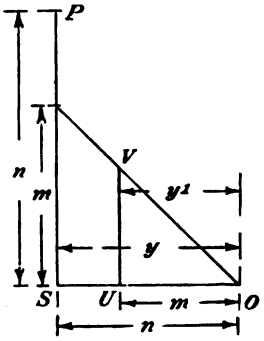

FIG. 5.—BEAM.

section between E and F, $S = wc + wx - W$. If $x = a$, $S = wc + wa - W = 0$, and hence there is no shearing force at the centre.

Taking the section on the left of F, but indefinitely near, $x = 2a$, and

$$S = wc + 2wa - W = wa.$$

To the right of the section, and close to it, $S = wa - W = -wc$. Proceeding from this point to the end of the beam, $S = wx^1 - wc$, and when at the end of the beam $x^1 = c$, $S = 0$.

Taking AB in Fig. 8 as a datum line, and setting off these quantities to scale, we obtain the straight line curves of shearing force, from which the value of S may be read off at any point. From the curve it is evident that the greatest shearing force occurs at E and F, and

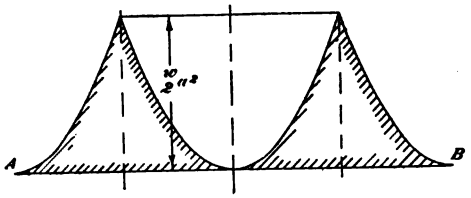

FIG. 6.—BEAM.

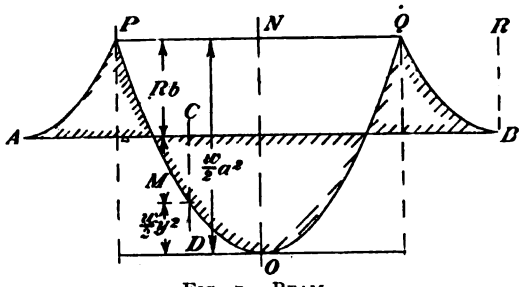

FIG. 7.—BEAM.

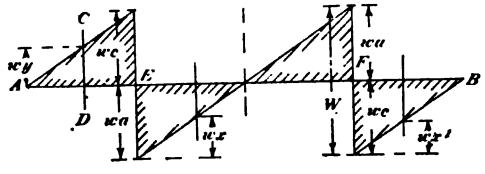

FIG. 8.—BEAM.

in the particular case given it has the same magnitude on either side of the section, since $c = a$. This is numerically equal to 28 lbs., since $c = a = 6$ ft., and $w = 4\frac{2}{3}$ lbs. per ft., but on one side of each section S is positive, whilst on the other it is negative.

GRAPHIC SOLUTION.—I shall be glad if you will give me a graphic solution of the following:—Given a line A B divided at C, a second line E D, and an arbitrary angle γ, find a point F on E D such that

$$\frac{A C}{E F} = \cos \alpha, \quad \frac{C B}{F D} = \cos \beta,$$

where $\alpha + \beta = \gamma$.

Let A C $= a$, C B $= b$, E D $= c$, F D $= r$, E F $= c - r$.

We have then to find r and α, where these quantities are connected by the equations

$$a = (c - r) \cos \alpha \quad . \quad . \quad . \quad . \text{ (i)}$$
$$b = r \cos (\gamma - \alpha) \quad . \quad . \quad . \quad . \text{ (ii)}$$

Considering r and α as the polar coordinates of a point, we see that the second equation represents a straight line distant b from the origin, the $\perp^r$ on the line from the origin (b) making an angle γ with the initial line (Fig. 1).

In rectangular coordinates we have

$$r \cos \alpha = x, \; r \sin \alpha = y, \text{ and hence}$$
$$b = x \cos \gamma + y \sin \gamma.$$

Equation (i) represents the "conchoid" of Nicomedes (*c.* B.C. 150); in mixed rectangular and polar coordinates we have

$$a = \frac{c x}{r} - x,$$

or

$$\frac{x}{r} = \frac{a + x}{c}.$$

This equation enables us to construct the curve. For let O A (Fig. 2) be the initial line, then set off a distance a in the negative direction; from the point thus found as centre describe a circle of radius c, from the origin draw a line O P parallel to any radius B Q, cutting the ordinate Q M at P. Then P is a point on the conchoid. As the radius B Q revolves, P will trace out the conchoid.

This way of looking at the conchoid gives an easy way of constructing the curve continuously. For B and O being fixed points, by joining B Q and O P by a bar of length a (the ends of the bar being pin-jointed to B Q and O P), we ensure O P being always parallel to B Q; if then a pencil P can slide along the rod P_1 P, a set square Q M, pushing Q round the semicircle will cause P to describe the conchoid.

Another way of describing the curve can be derived as follows: writing $-x$ for x we get

$$\frac{x}{r} = \frac{x - a}{c};$$

hence draw a line $\perp$ to initial line at a distance a from origin; draw any ray through origin, and set off from its intersection with the fixed line, a segment c in both directions. The locus of the points thus determined is the conchoid.

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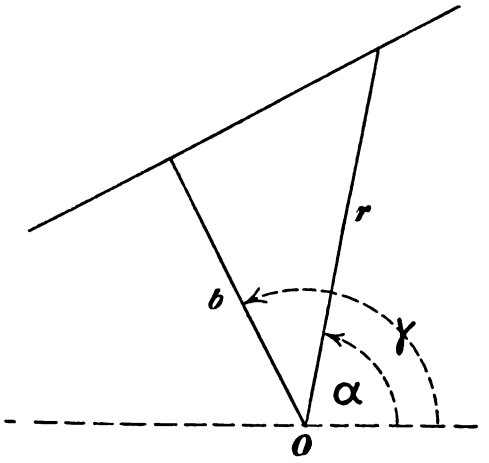

FIG. 1.—GRAPHIC SOLUTION.

The intersections of the line

$$b = x \cos \gamma + y \sin \gamma$$

with the conchoid

$$\frac{x}{r} = \frac{x + a}{c}$$

will give the various values of r and a possible. Of course all values of a greater than γ are inadmissible. How many solutions there are to the problem depends on the magnitude of $a, b, c,$ and γ. For instance, the adjoining sketch (which is not drawn to scale) of the curve shows that for $\gamma = 90°$ there may be 2, 1, or no values of r. As figured, O A and O B are the two values of r.

A list of modern instruments for drawing the curve may be found in Dyck's "Katalog der Münchener Mathematischer Ausstellung von 1893."

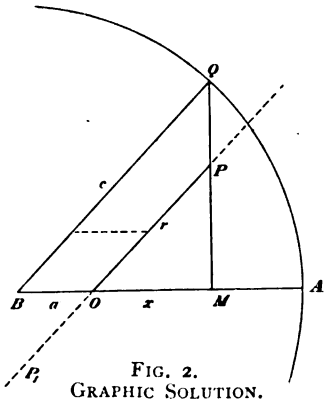

FIG. 2.
GRAPHIC SOLUTION.

NAVAL ARCHITECTURE.—Having given the projection of the centre line of hawse pipe in sheer and half breadth plans, and the diameter of the pipe, show how to obtain the development of the tine in which the surface of the hawse pipe meets the outer surface of the bow plating.—*Question* 89, *Naval Architecture Honours, Part II.*, 1900.

This is a particular case of the problem in descriptive geometry to find the intersection of a right circular cylinder with a given surface.

In the figure the surface for convenience is taken so that the sections A.B. · · · · F and the level lines 1.2.3. · · · · 11. are straight in body and in the half breadth. The projections of the centre of pipe are aT and $a's$. respectively.

Draw the sides of cylinder in plan bX, cP, and also a convenient number of parallels Q.R · · · V.W. Project the intersection of the surface of ship with vertical planes P.Q.R. etc., on to a new vertical plane perpendicular to the horizontal projection aT. These intersections will be curved as shown. In this new vertical plane draw the axis of cylinder making angle θ with upright (θ being the angle the axis of cylinder makes with upright). Draw also sides of cylinder. On base aa draw semicircle, and draw dotted lines same distance from centre as S.R.Q. U.V.W. Where these lines cut semicircle will give projections in the new vertical plane of intersection of vertical planes Q.R. · · · · with the surface of cylinder. Pick out corresponding

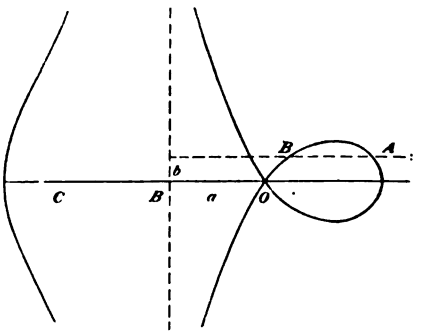

FIG. 3.—GRAPHIC SOLUTION.

lines. aT in plan is plan of top and bottom of cylinder. These are in elevation the extreme lines of cylinder. Thus qr and st are elevations of kQ and dW in plan. Corresponding intersections of these lines on cylinder surface with ship's surface can then be picked out in the new vertical plane. Thus m where qr meets curve W is a spot in new elevation, and so on from which elevation may be drawn *lmop*. This can be transferred to plan by picking out intersections with level lines 4·5 etc. The plan of intersection can then be transferred into the original elevation in the ordinary way, and this is the elevation of the hole. We thus have a line given in plan and elevation, and we can obtain the development by projecting over to the body and then expanding fore and aft, the true length on each level line being given in the half breadth and expanding on each vertical section, the true length being given on the sections in the body.

B.Sc.—Kindly recommend a suitable course of reading for the London B.Sc. (Final) in Pure and Applied Mathematics.

(1) *Pure Mathematics.*

Hall and Knight's Higher Algebra, omitting

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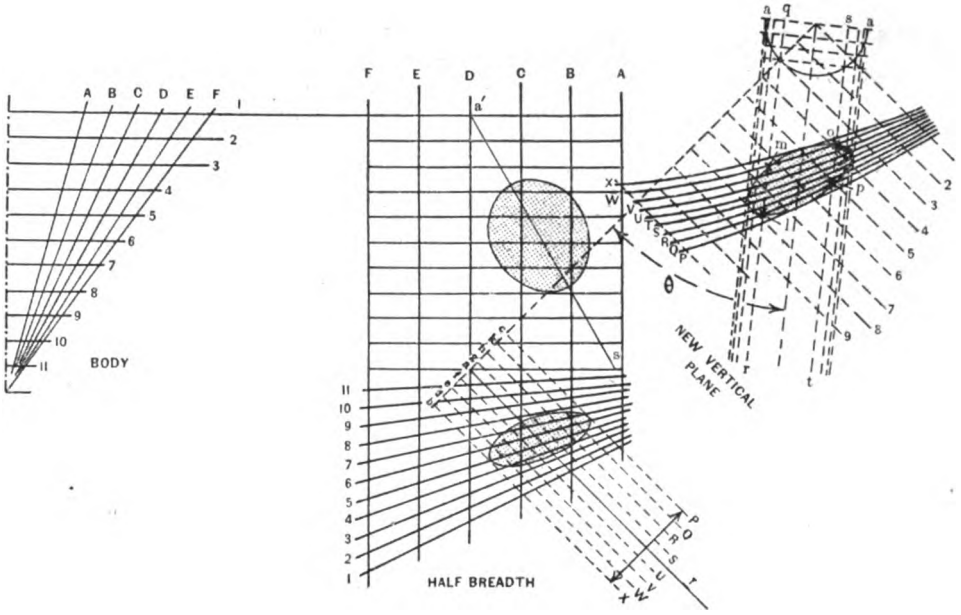

FIG. 1.—NAVAL ARCHITECTURE.

the last part of the chapter on convergency and divergency of series, and the chapters on recurring continued fractions, indeterminate equations of the second degree, general theory of continued fractions, probability, and most of that on the theory of numbers.

In trigonometry, supposing a thorough knowledge of Hall and Knight's Elementary Book, it would be sufficient to work through the last part of Lachlan and Fletcher's "Elements of Trigonometry." The usual book is, however, Lock's Higher Trigonometry; it contains far more than necessary.

In geometry, some work such as Cockshott and Walters' Conics, or Wilson's Conics (the latter would really be sufficient) should be mastered, and in addition, parts of Russell's Elementary Treatise on Pure Geometry (roughly speaking, Chapters I.–V., IX., XI., XIV., XV., and XXIV. should be quite sufficient). Part III. of Budden's Elementary Pure Geometry contains nearly enough, so that this is recommended if the other works are at hand for reference.

For analytical geometry, C. Smith's Conic Sections is the best book. The chapters on trilinear and tangential equations and on general systems of conics, and the parts on involution and reciprocal polars may be omitted.

Edwards' Differential Calculus for Beginners should be thoroughly known, and very little of it can be safely omitted.

Edwards' Integral Calculus for Beginners contains a good deal more than is necessary.

(In working examples from Edwards' books, those towards the end of each set of exercises may usually be omitted; their solution often depends on some algebraical or trigonometrical trick.)

Most of the first six chapters should be mastered; a general knowledge of Chapter VII. would be sufficient. Chapters IX., X., and XI., on Lengths, Areas, and Volumes, must be known, with the exception perhaps of those parts on pedals.

The rest of the book may be omitted.

(2) *Mixed Mathematics.*

Either MacGregor's Kinematics and Dynamics or Loney's Statics and Dynamics, and Loney's Elementary Dynamics must be known well. MacGregor's book is in many ways preferable, but too diffuse. As a knowledge of the application of the calculus to mechanics is now necessary, the above must be supplemented by either Besant's, Routh's, or Love's Dynamics. In Besant's Dynamics, the following parts would be found amply sufficient: §§ 3–15, 22, 30, 32, 35–55, 58–68, 72–75, 78, 79, 81–83, 101–108, 136–141, 212, 217, 219, 220, 222, 225, 239–245, 247, 250, 260, 261.

It would be as well also to supplement the Statics already known by reading the articles on the general equilibrium of forces and on inextensible strings in Todhunter's or Minchin's Statics.

For hydrostatics, Besant's Elementary Book will probably be sufficient; the evasions of the calculus can easily be replaced by the direct calculus method.

For "Vectors and Rotors," the little work under that title by Professor Henrici, F.R.S., and G. C. Turner should be consulted, as it contains the application to graphical statics. Most of the purely geometrical part may be omitted. Examples for graphical statics occur also in Loney and MacGregor.

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MATHEMATICS.—Please let me know the best books on the following subjects; the standard being the Cambridge Mathematical Tripos:—

1. *Differential and Integral Calculus.*

"Edwards' Differential Calculus for Beginners" (Macmillan, 4s. 6d.).

"Edwards' Integral Calculus for Beginners" (Macmillan, 4s. 6d.).

In addition, "Greenhill's Calculus" (Macmillan, 10s. 6d.) should be consulted.

2. *Differential Equation.*

A good deal of the theory of ordinary differential equations is contained in "Edwards' Calculus." For more advanced work in ordinary and in partial differential equations, "Forsyth's Treatise on Differential Equations" (Macmillan, 14s.) is necessary.

3. *Analytical Solid Geometry.*

"C. Smith's Solid Geometry" (Macmillan, 9s. 6d.), or "Aldis' Solid Geometry" (Deighton, Bell, 6s.). The latter really contains quite sufficient for all ordinary purposes, and is easier.

4. *Modern Algebra.*

"Chrystal's Algebra," Part I. (Sonnenschein, 10s. 6d.) is the really modern one, but is somewhat diffuse, and students find difficulty in getting a real grip of it.

"C. Smith's Algebra" (Macmillan, 7s. 6d.) is excellent, but the book that finds most favour is "Hall and Knight's Higher Algebra" (Macmillan, 7s. 6d.).

5. *Theory of Equations.*

Burnside and Panton (Dublin University Press), 12s. 6d.; London agents: Longmans, Green, and Co.

6. *Universal Algebra and Non-Euclidian Geometry.*

"Whitehead's Treatise on Universal Algebra, with Applications" (Cambridge University Press). This work is of an advanced character. If by non-Euclidian geometry is simply meant modern or projective geometry, it would be best to read the article by Professor Henrici, F.R.S., on geometry, in the "Encyclopædia Britannica" (Edition IX.), and then "Cremona's Projective Geometry" (Clarendon Press, 12s. 6d.). The usually read Oxford book on modern geometry is "Russell's Elementary Treatise on Pure Geometry" (Clarendon Press, 10s. 6d.): it is much easier to read.

ANALYSIS.—What is the best book on the chemical analysis of oils and varnishes?

The best book on this subject is "Chemical Technology and Analysis of Oils, Fats and Waxes." By Dr. J. Lewkowitsch (Macmillan and Co., 1905). Price 36*s.* net.

POLYGON.—What are the best books on the following branches of mathematics, suitable for an engineer requiring advanced mathematical knowledge?—

1. *Differential Equations.* — A Treatise on Differential Equations, by A. R. Forsyth (Macmillan and Co.).

2. *Elliptic Functions.*—An elementary account of these will be found in Todhunter's Integral Calculus (Macmillan and Co.), pp. 201–210.

3. *Fourier's Analysis, Spherical and Ellipsoidal Harmonics, and Bessel Functions.*—"An elementary treatise on Fourier's Series, and spherical, cylindrical, and ellipsoidal harmonics, with application to problems in mathematical physics." By W. E. Byerly (Ginn and Co., Boston, U.S.A.).

4. *Calculus of Finite Differences.*—"A treatise on the calculus of Finite Differences," by G. Boole (Macmillan and Co.).

5. *Calculus of Variations.*—A chapter on this subject will be found in Todhunter's Integral Calculus (Macmillan and Co.), pp. 322–372. *See* also Researches in the Calculus of Variations, by Todhunter (Macmillan and Co.).

6. *Applications of Conjugate Functions. See* Lamb's Treatise on the Motion of Fluids.

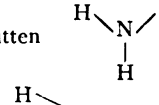
7. *Determinants.*—An elementary account of determinants is given in "The Elements of Co-ordinate Geometry," by S. L. Loney (Macmillan and Co.). The standard work is "The Theory of Determinants," by R. F. Scott and G. B. Mathews (Cambridge University Press). Price 9*s.* net.

For other subjects, *see* answers to "B.Sc." and "Mathematics."

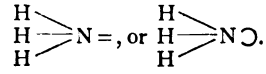
CHEMISTRY.—Discuss the structural formula of carbon monoxide.

A constitutional formula, if it is to be at all acceptable, should be capable of explaining the principal reactions of the compound it represents; but in framing it due regard must be paid to generalisations which appear to hold in other compounds containing the same elements.

Constitutional formulæ were first employed to explain certain apparently general laws regulating the composition and structure of carbon compounds, and it has been found almost invariably possible to represent these with quadrivalent carbon. On this assumption, if the oxygen atom is divalent, the formula employed for carbon monoxide must be written as $C{<}{=}O$ or $>C=O$, formulæ which really involve the view that the carbon is here acting as a divalent element; hence the formulæ may both be expressed as $C=O$, the fact that the carbon may become quadrivalent by uniting with certain other atoms or groups being here implicitly understood, as is the similar property of the nitrogen atom in ammonia, which is usually written



and not



The alternative view is that the carbon acts in its normal way as a quadrivalent element, but that the oxygen atom is also quadrivalent: thus, $C{\equiv}O$. There is, perhaps, less to recommend this than the other hypothesis, for

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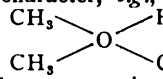
although of late years a considerable weight of evidence has led to a fairly general belief that oxygen may behave as a quadrivalent element, yet this is apparently only the case when the product is salt-like in character, *e.g.*, in the "oxonium" salts such as  , and in this respect quadrivalent oxygen is exactly analogous to quinquivalent nitrogen, which is found in the ammonium and diazonium salts.

Returning, for this reason, to the first formula suggested, it becomes worth while to enquire (*a*) whether the properties of carbon monoxide are in accordance with the requirements of the formula, and (*b*) whether any other compounds of carbon are known, in which evidence of the presence of divalent carbon can be discovered.

With regard to the first point, it may be said that in all the reactions in which carbon monoxide combines directly with other compounds, it is to the carbon atom alone that addition appears to take place. Thus, with oxygen and chlorine, the products are O:C:O and $Cl_2C=O$, and a number of others might also be cited.

With reference to the second point, there is a good deal of evidence in favour of the existence of other compounds containing divalent carbon, and chemists are indebted to Nef for most of our information on this point. He has pointed out, for example, that the "carbylamines" (or "isocyanides") contain a carbon atom which is very prone to attach itself directly to other atoms or groups, and it is now becoming customary to write the formulæ of these compounds with the group $-N=C$. The older method of representing this group, namely, as $-N\equiv C$, did not so readily explain the special reactivity of the carbon atom, and, moreover, required the assumption that there was a quinquivalent nitrogen atom present, although the compounds had none of the characters of salts.

In a similar way, it has become a common practice to represent the metallic cyanides as having the same group, *e.g.*, $K-N=C$ (which may be regarded as the potassium derivative of the imide of carbon monoxide $H-N=C$), whilst the fulminates are also written as derivatives of the oxime of carbon monoxide $H\cdot O\cdot N=C$. There is experimental justification for these assumptions, but considerations of space prevent the insertion of details here.

In conclusion, then, there appears to be more evidence in favour of the formula $C=O$ for carbon monoxide than for any other which can be suggested on the lines generally followed in framing structural formulæ.

TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

DEAR SIR,—The following method of dealing with the integrals already evaluated in your columns seems to me much more intelligible and interesting than making random substitutions :—

(1) $\int_0^{\pi} \frac{x \tan x}{\sec x + \tan x}\,dx$ (2) $\int_0^{\pi} \frac{x \tan x}{\sec x + \cos x}\,dx$

(1) reduces to $\int_0^{\pi} \frac{x \sin x}{1 + \sin x}\,dx.$

(2) reduces to $\int_0^{\pi} \frac{x \sin x}{1 + \cos^2 x}\,dx.$

The symmetry of the sine and cosine graphs suggests shifting the origin to the middle of the range 0 to π.

Hence, putting $x = z + \frac{\pi}{2}$,

(1) becomes—

$$\frac{\pi}{2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\cos z}{1 + \cos z}\,dz + \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{z \cos z}{1 + \cos z}\,dz.$$

(2) becomes—

$$\frac{\pi}{2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\cos z}{1 + \sin^2 z}\,dz + \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{z \cos z}{1 + \sin^2 z}\,dz.$$

Now a glance at the sine and cosine graphs shows that $\cos z$, $(1 + \cos z)$, and $(1 + \sin^2 z)$ are all positive throughout the range $-\frac{\pi}{2}$ to $+\frac{\pi}{2}$; therefore for every negative value of z, and therefore of

$$\frac{z \cos z}{1 + \cos z} \text{ and } \frac{z \cos z}{1 + \sin^2 z}$$

between the limits $-\frac{\pi}{2}$ and 0, there is an equal positive value between 0 and $\frac{\pi}{2}$.

Hence

$$\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{z \cos z}{1 + \cos z}\,dz \text{ and } \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{z \cos z}{1 + \sin^2 z}\,dz$$

are each equal to zero.

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Thus (1) becomes—

$$\frac{\pi}{2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\cos z}{1+\cos z}\,dz = \frac{\pi}{2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[1 - \frac{1}{1+\cos z}\right] dz$$

$$= \frac{\pi^2}{2} - \frac{\pi}{2}\left[\tan\frac{z}{2}\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$= \frac{\pi^2}{2} - \pi$$

(2) becomes

$$\frac{\pi}{2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\cos z}{1+\sin^2 z}\,dz = \frac{\pi}{2}\left[\tan^{-1}(\sin z)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

which, with the usual restriction on $\tan^{-1}$, is equal to $\frac{\pi^2}{4}$.

Yours etc.,
G. AIMER RUSSELL.

4, Manse Street,
Kilmarnock, Scotland.
28th March, 1905.

To the Editor of TECHNICS.

DEAR SIR,—In the current number of TECHNICS, an error, I fancy, appears in the description of Threlfall's apparatus on p. v. of "Industrial Progress," as also on p. 303. The statement that

$$v^2 = 2gh, \quad \text{or} \quad k^2 \times 2gh,$$

applies only when the fluid possessing the velocity v is the same as that having the difference of level h. If v refer to air, and h be measured by water,

$$v^2 = \frac{2gh}{d},$$

where d denotes the density of air relatively to water. Or, adopting Stanton's correction,

$$v = k\sqrt{\frac{2gh}{d}}.$$

With congratulations on the excellence of the magazine, I am,

Yours faithfully,
W. R. KELSEY.

Divary Cottage,
Taunton.
11th April, 1905.

To the Editor of TECHNICS.

DEFECTS IN TIMBER.

SIR,—On page 168 of your February issue Mr. Busbridge gives an illustration (Fig. 9) of a "Transverse Shake," and accounts for it by assuming that the tree, in its earlier life, had been subjected during a hurricane to excessive bending stress, and that the fibres may have been severed on the tension side or crushed on the compression side. From experiments on timber struts, carried out recently by some students in the mechanical engineering laboratory here, it appears that this is the common appearance of the material in the neighbourhood where failure begins. The excessive stress produces what appears to be a wrinkling of the material in the locality of failure.

This is probably due to the failure of the walls of the cells (in compression) without severance of the fibres, thus permitting a slight lateral movement and producing the appearance of wrinkling.

I am inclined to think that the "transverse shake" occurs on the compressed side of the tree, because if the fibres were severed on the side in tension, the strength of the tree to resist bending would be so much reduced as to produce breakage. If wrinkling occurred as in a piece in compression, the tree would probably not break in two parts unless longitudinal splitting occurred simultaneously; this we find is the last stage in the strut's destruction.

Yours truly,
W. W. F. PULLEN.

South-Western Polytechnic,
Manresa Road, Chelsea,
London, S.W.
6th April, 1905.

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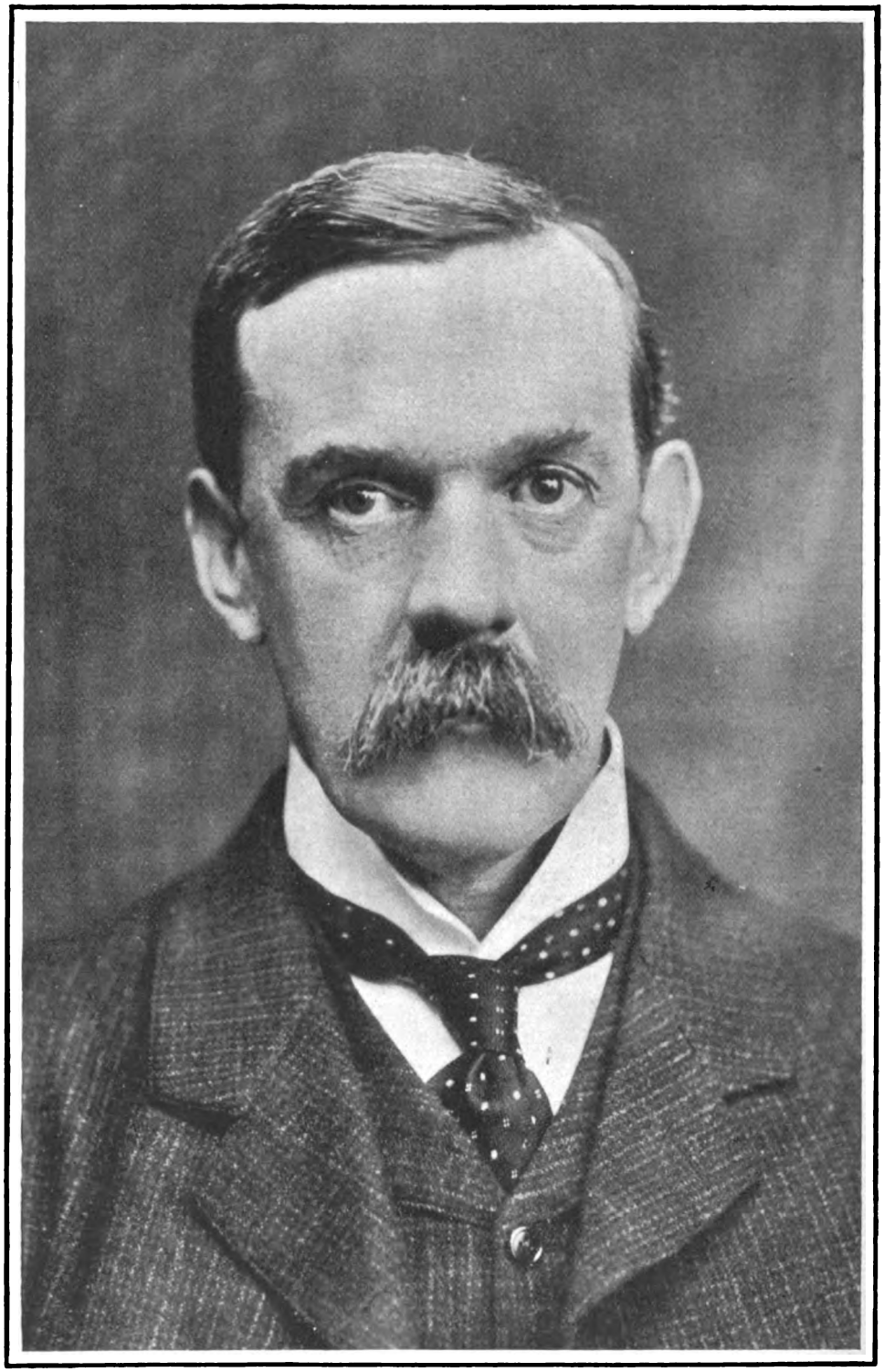

RICHARD TETLEY GLAZEBROOK, M.A., Sc.D., F.R.S.

Director of the National Physical Laboratory.

Photo by Geo. Newnes, Ltd.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. III. JUNE, 1905. No. 18.

PROGRESS OF SCIENCE AND TECHNOLOGY.

MR. R. T. GLAZEBROOK was born on September 18th, 1854, being the eldest son of Mr. Nicholas Smith Glazebrook, of Liverpool. He was educated at Liverpool College, and Trinity College, Cambridge, and wrangled fifth in 1876. He became a Fellow of Trinity College, Cambridge, in 1877, Senior Bursar in 1895, and for several years held the position of Assistant Director of the Cavendish Laboratory, Cambridge. Mr. Glazebrook took an active part in the determination of the electrical standards which are to-day used throughout the world. In 1898 he was appointed Principal of University College, Liverpool, and in the following year became Director of the National Physical Laboratory, Bushy House, Teddington; the valuable services rendered to the technical industries by that institution testify to his ability as an organiser of research. Mr. Glazebrook has contributed a great number of papers on mathematical and physical subjects to the learned societies, and his books on various branches of physics are well known to students.

Mr. Glazebrook and the Optical Convention

The Optical Convention, which was opened at the end of May, owes its origin in great part to the interest taken by Mr. Glazebrook in the optical industries of this country. The remarkable advances effected in the past by Continental firms, such as Zeiss and Schott, of Jena, have tended to obscure the very real progress recently made in this country. Manufacturers of the United Kingdom have always been noted for the sound work put into the instruments they made; in the past their chief failing has arisen as a natural result of their early success, together with the idea engendered in such circumstances that, having attained to a position of eminence and world-wide renown, further research as an aid to improved methods is unnecessary. A brief account of the exhibits at the Optical Convention, which will be found elsewhere in this issue, shows that the optical industries of the United Kingdom now compare favourably with those in foreign countries. It is satisfactory to find that Messrs. Chance are now in a position to make any kind of glass, so that optical instrument manufacturers will no longer have to go abroad for this. It may be stated with confidence that many instruments exhibited, such as those designed and made by Sir Howard Grubb, F.R.S., are quite unequalled by anything made abroad. There are many cases in which it is necessary to make a rough survey under conditions which render speed of the utmost importance; in such cases Sir Howard Grubb's instruments are simply invaluable, and their sphere of usefulness will doubtless become even greater with the progress of time.

Death of Mr. R. H. Housman

IT is with the greatest regret that we hear of the death of Mr. Robert Holden Housman, which occurred at Bath, at the residence of the deceased gentleman's sister, on Tuesday, May 2nd. The following obituary notice is copied from the *Birmingham Daily Post*; we understand that it was written by Professor J. H. Poynting, F.R.S., who was a personal friend of the deceased.

Mr. Housman came to Bath to stay at the residence of his brother-in-law (Mr. E. W. Symons, head-master of King Edward's School), for Easter. On Friday, April 28th, he went out with one of his four nephews on a roving expedition, and in the course of it waded through water. A chill was the result, and, acute inflammation developing, death ensued after only three days' illness.

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The deceased gentleman was the second son of Mr. Edward Housman, of Perry Hall, Bromsgrove. He was educated at Sydney College, Bath, and at Bromsgrove School. In 1882 he entered Mason College, being one of the first students in engineering; and at the end of his course he was made one of the first associates of the college, a distinction which led to the degree of B.Sc., which was conferred on him in 1901, when the college was merged into the University. On leaving Mason College Mr. Housman was, for some years, with Messrs. Chamberlain and Hookham, where he obtained valuable experience in dynamo and general electrical work, and later he was engaged in similar work in London. In 1895 he was elected to the newly-created post of lecturer on electrical engineering at Mason College, and he established and organised the laboratory in electrical engineering, which is now to be under the care of Professor Kapp, at Bournbrook. While at Mason College he devised, at the same time as Mr. Kapp, the well-known Kapp-Housman test for separating the "no-load" losses which occur in dynamo machinery. Up to the time of his death he took an interest in technical electricity, and was an active member of the local branch of the Institution of Electrical Engineers, and a member of the committee.

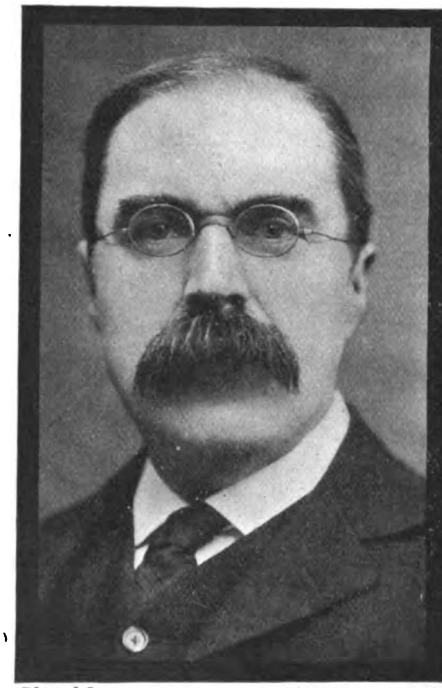

Photo by] [*Geo. Newnes, Ltd.*

THE LATE ROBERT HOLDEN HOUSMAN.

After holding the lectureship for three years, he resigned it when he was appointed scientific adviser to Kynoch's in 1898. Here he was able to take up a study for which he had always had great enthusiasm —the study of "ballistics," or the theory and practice of ammunition and shooting. He was an excellent shot; during his ten years' membership of the 2nd Worcester Volunteers he was champion shot of his company seven times, of his battalion three times, three-counties champion once, and for some years he held the Martini record with 102. He had always taken great interest in the theory as well as the practice of shooting, and had already carried out a series of experiments. At Kynoch's he found the opportunity to continue his favourite pursuit, and with most remarkable ability and experimental skill he devised methods of measuring the pressure of the powder and the velocity of the bullet at every point in its course along the barrel of a rifle. Some of the results he drew from his experiments have been published.* Only lately he devised an improvement in the composition and form of cordite, which led to a most marked increase in the muzzle velocity of the 0·303 bullet of the Service rifle. It is very much to be regretted that he had great difficulty — a difficulty which he seldom overcame — in preparing his work for publication. What he has published gives a very inadequate idea of his ability—an ability that was only known and fully recognised by his intimate friends. To them it was ever surprising to find how easily he seized on the essential points in any scientific problem, how clearly he grasped the question, and how readily he thought of the means of finding a solution. A talk with him on any technical or physical subject was most stimulating, and his scientific friends could always be sure of sympathetic and helpful advice. He was a man of wide culture outside his scientific pursuits, and his personal qualities won him the respect and warm regard of his colleagues at the Mason College, and later at Kynoch's.

Heusler's Magnetic Alloys

HEUSLER'S discovery that a magnetic alloy can be produced by mixing copper, manganese, aluminium and other metals together is being followed up by the staff of the Reichsanstalt: a paper by E. Gumlich

* "The Ballistics of Modern Rifles," by R. H. Housman. TECHNICS, No. 13, January, 1905; Nos. 14 and 15, April and May, 1905; and the current issue, pp. 500 to 502.

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was published in the *Electrotechnische Zeitschrift* for March 2nd. Two alloys have been studied, their composition being as follows:—

	Copper.	Manganese.	Aluminium.	Lead.
	Per cent.	Per cent.	Per cent.	Per cent.
Alloy I.	61·5	23·5	15	0·1
Alloy II.	67·7	20·5	10·7	1·2

Alloy I. was brittle, but alloy II. could be worked easily. A magnetising field of 160 c.g.s. units produced an induction B equal to 4270 c.g.s. units in alloy I., and 3120 in alloy II. The maximum permeability of both alloys is about equal to that of good cast iron; it increases with age, and may become nearly equal to that of cast steel.

On the other hand, the maximum permeability corresponds to a low magnetic induction. For B = 1100, the value of μ is 1200: for B = 3000 the value of μ has fallen to 35. The hysteresis loss, for the maximum values of B given above, was 7560 ergs per c.c. for I., and from 250 to 1500 ergs per c.c. for II. The values of Steinmetz's hysteresis coefficient were 0·0117 for I., and 0·003 for II.

Photometry of Street Lamps

Some interesting photometric tests of street lamps have recently been carried out by the staff of the National Physical Laboratory. Two streets in Teddington had been equipped, one with gas lamps and the other with electric incandescent lamps. The gas lamps consumed 4 to 4½ cubic feet of gas per hour, and were fitted with "C" burners and ordinary incandescent mantles. The electric lamps were of the Nernst vertical filament "A" type, and the Nernst Luna type, each taking nominally 0·5 ampere at 240 volts, or 120 watts. The two systems were compared by measuring the illuminations produced at a height of 5 feet above the ground, and at a distance of 7 feet from the respective lamp-posts. Experiments showed that the illuminations at greater distances from the lamps bore the same ratio as those at the above distances. As a result, it was found that to produce 0·5 candle-foot illumination (*i.e.*, an illumination equal to half of that at a foot distance from a standard candle) 8·2 cubic feet of gas were required to be burnt per hour, while 0·098 B.T.U's. were required for the Nernst Luna lamps, and 0·17 B.T.U's. for the Nernst vertical filament lamps. The cost of the gas illumination with gas at 2s. 6d. per 1000 cubic feet would be 0·246d. per hour, while that of the electric light, with electricity at 4·5d. per B.T.U., would range from 0·441d. per hour for the Nernst Luna, to 0·756d. per hour for the Nernst vertical filament lamp. Of course, the relative values of electricity and gas vary considerably in different districts, but the above may be taken as fair average figures. In carrying out these tests, a portable Simmance-Abady "flicker" photometer was used. In this the photometer head and the standard lamp are fixed; the latter is a standardised electric incandescent lamp, of 2 candle-power at 10 volts, to which current is supplied by a portable battery of accumulators; and by varying the voltage across the lamp terminals, the candle-power can be varied over a wide range. The lamp had previously been calibrated, its candle-power for a number of voltages was determined experimentally, and a curve connecting voltage and candle-power was plotted.

Strength of Boiler Furnaces

An important paper on the design of boiler furnaces was read by Mr. D. B. Morison, before the North-East Coast Institution of Engineers, on April 14th, 1905. The furnace is an important factor of boiler efficiency—about 60 per cent. of the total steam being generated from its surface—and its collapse is almost invariably attended by so serious a wastage of capital that the principles and practical conditions affecting its correct design, and the maintenance of the highest attainable strength and efficiency in actual work, are well worthy of the serious consideration of those responsible for its performance.

The Board of Trade, Lloyd's Registry, and other registration societies assign strength-values to various types of furnaces by subjecting them to external hydraulic pressure, until collapse takes place. The furnace to be tested is rivetted into a strong steel cylinder (Fig. 1), the space between the outer surface of the furnace and the inner surface of the cylinder being filled with cold water, the pressure of which is raised until the furnace collapses, and from this result a coefficient of resistance to collapse is obtained by the following formula:—

$$\frac{P \times D}{T} = \text{collapsing coefficient.}$$

P = collapsing pressure in lbs. per sq. in.
D = outside diameter of furnace in inches.
T = thickness in inches.

These collapsing coefficients are accepted by boiler manufacturers, shipowners, and

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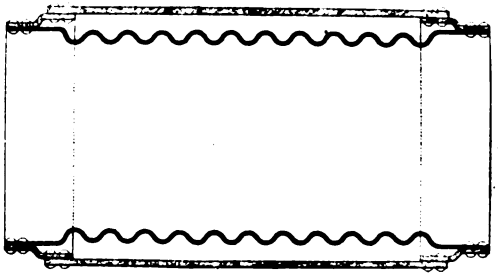

FIG. 1.—FOX FURNACE IN TESTING APPARATUS.

others as correctly indicating the comparative strength-values of the various types of furnaces, and are used by designers in calculating thickness.

An important factor which does not appear in this calculation is the strength of the material. The range of tensile strength allowed by the Board of Trade, Lloyd's, and Bureau Veritas is from 26 to 30 tons per square inch, but the British Corporation require 25 to 29 tons. In calculating the comparative resistance to collapse from cold water destructive tests, one definite mean value of the tensile strength should be taken, as a most untrustworthy comparison would result if one type of furnace made of 26 tons steel were compared with another type of 30 tons, and a coefficient assigned to each without any adjustment for the difference of four tons in the tensile strength. The limit thickness allowed for furnaces by all the surveys is three-quarters of an inch. The object of the designer is to obtain the greatest ultimate resistance to collapse for a given thickness, whilst that of the responsible advisers of the various registration societies would seem to be maximum safety when in use in a boiler, and a trustworthy comparative adjustment of collapsing coefficients for the guidance of manufacturers and users.

Mr. Morison strongly urged that the ultimate strength of a boiler furnace cannot be determined by the cold water destructive test; the fact that designs, which were awarded high constants, have been completely displaced in practice by other designs to which practically the same values were given, would seem to justify this contention. The tests carried out by the Board of Trade, Lloyd's Registry, and other registration societies, only determine the resistance to collapse of a clean, cold tube when subjected to the pressure of cold water. Experience has proved this to be an entirely untrustworthy measure of the strength of the same tube when used in a boiler under actual working conditions, and such tests cannot correctly determine the relative strength values in actual work of different designs. It is granted that this method of testing is necessary and instructive; but to assign to a tube a strength value derived from a test under conditions bearing no resemblance to those to which it will be subjected when in use as a boiler furnace, may be dangerously misleading to those who are accustomed to accept the regulations of the controlling bodies without investigation.

Cause of Collapse of Boilers

THE strength value of a furnace can be estimated only by its behaviour when in use in a boiler under severe conditions of work. If the wall of a furnace were always clean and a good conductor of heat, so that the temperature of the metal never largely exceeded the temperature of the steam, then the furnace would never deform, because in that condition it would be capable of withstanding (according to Board of Trade regulations) about five times the load which could ever be imposed upon it by the steam pressure. Therefore, a furnace deforms or collapses only when a portion of its wall becomes so overheated as to reduce the strength of the metal by an amount which renders it incapable of resisting the pressure to which it is subjected; and it follows that the safety of a furnace does not depend so much upon the strength theoretically derivable from any particular form of tube, as upon the ability of that form to minimize the possibility of local overheating and to safely withstand the weakening effect of overheating, should it by any chance occur. It is, consequently, possible for a tube to be of great strength when subjected to cold water external pressure, and yet be practically a failure as a furnace in a boiler.

Types of Furnaces

THE various types of cylindrical furnaces may be divided into the following classes:—

1. Plain cylindrical tubes, straight in longitudinal section throughout their length.
2. Plain cylindrical tubes, strengthened by flanges, hoops, corrugations, or ribs, at intervals throughout their length.
3. Furnaces wholly curvilinear throughout their length.

Corrugated furnaces of all types enable large diameters to be employed, and the diameter of the furnace has a direct influence on the efficiency of a boiler. At present, the strength coefficient granted by the Board of Trade, etc., is constant for all diameters, but

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the tendency to deform, occasionally shown by furnaces of large diameter, especially under forced draught, seems to indicate that a more uniform margin of safety would be secured if the rules of the registration societies provided a coefficient remaining constant up to, say, three feet six inches internal diameter, and decreasing proportionally as the diameter of the furnace increases.

With a given weight of material the maximum resistance to collapse under uniformly distributed external pressure is offered by a mathematically true cylinder, by reason of the fact that the stress throughout the material is of uniform character, *viz.*, compressive. In actual practice it is, however, impossible to produce a mathematically true cylinder, and, if it were possible to produce, it would be impossible to maintain under working conditions. The effect of any departure from the true form is to vary the nature of the stress at different points, and to distribute the stresses unequally throughout the structure.

Strength of Furnace

THE strength of a plain cylindrical tube varies directly as its thickness, and inversely as its diameter. Experiments on furnaces have demonstrated that large diameters are weaker than this proportion; and although there is no reason why a theoretically perfect cylinder should be inversely affected by its length between its end connections, yet such has been proved to be the case with furnace tubes. No doubt this is again due to the difference between the conditions of the material under stress in the hypothetical perfect cylinder and the imperfect cylinder of practice.

It is evident from the above consideration that it is requisite to strengthen the imperfect cylinder of practice against bending stresses. This cannot be done by thickening the metal beyond a fixed narrow limit, and a remedy has to be provided by so disposing the material as to offer to the aforesaid bending stresses the maximum resistance per unit of weight. The earlier methods adopted were to provide at intervals annular rings, such as Bowling hoops, etc. (Figs. 2 and 3), possessing a very much greater resistance to collapse than the plain portions of the cylinder, and in order to comprehend the later developments it is necessary to understand the principles underlying this source of strength.

If a cylinder be provided with stiffening rings, it is evident that these rings will not be deformed under a stress which is quite sufficient to collapse the intervening metal, so that they constitute fixed points of support, between which deformation of the cylindrical form can only take place by the extension of the metal.

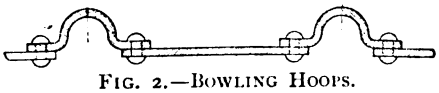

FIG. 2.—BOWLING HOOPS.

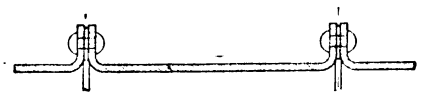

FIG. 3.—ADAMSON RINGS.

In illustration of the above remarks, let us consider the case of a plain furnace of imperfect cylindricity, with outward rings at intervals and with local accumulation of scale between the rings (Fig. 4). The metal below the deposit ultimately becomes so overheated and weakened that it cannot resist the steam pressure. If this affected area of plate be isolated in one's mind for the purpose of analysis, it resolves itself into a flat strip or beam supported at the ends by strong girder rings, and less effectively supported at the sides by the contiguous and less heated portions of the furnace wall. The central portion of the beam becoming weakened and

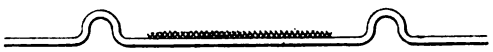

FIG. 4.—SECTION OF CORRUGATED FURNACE, SHOWING LOCAL ACCUMULATION OF SCALE.

plastic, deforms inwardly by bending; and it is this characteristic weakness of form that determines the ultimate strength of all furnaces which are straight in longitudinal section in any portion of their length. Excluding external separate supports, such a furnace can be strengthened only by increasing its thickness, or decreasing the distance between the strengthening rings.

Purves Furnace

MR. PURVES was the first to make the strengthening rings integral with the cylindrical tube (Fig. 5), thereby eliminating rivetted joints, making it practicable to greatly reduce the distance between the ridges, and increasing the strength of the furnace in a marked degree. To increase the strength of the ridges he made the metal therein thicker than the rest of the tube; but the unequal distribution of material caused unequal distribution of the stresses, which, combined with local concentration, at the base of the ribs, of the movement due to expansion and contraction, gave rise to circumferential fractures, and led to many subsequent modifications.

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FIG. 5.—PURVES FURNACE.

FIG. 6.—FOX FURNACE.

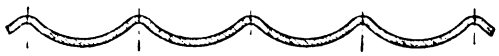

FIG. 7.—SUSPENSION FURNACE.

THE FOX furnace (Fig. 6) differed essentially from all its predecessors; it was entirely curvilinear in longitudinal section, and the more favourable conditions thereby established throughout the material constituted a distinct advance in the art of furnace manufacture. The essence of the Fox invention lay in the complete absence of plain cylindrical surfaces with their inherent weakness. He retained the old-fashioned Bowling ring as a ridge, and, by inverting it, obtained a curved valley; and he made his ridge and valley identical in proportions. Owing to the large amount of metal disposed in planes normal to the axis of the furnace, great strength was derivable from this particular form when tested as a tube by hydraulic pressure; but, as previously stated, the utility of a furnace depends on its ability to withstand severe usage in a boiler, and experience proved that much of the initial strength of a Fox furnace was soon lost by the concentration of deposit in the narrow valleys causing a weakening of the metal by overheating. Another practical defect was the loss of evaporative efficiency, caused by the sheltering of the outward by the inward corrugations, and by the partial stagnation of gas in the former.

Fox Furnace

THE introduction of the "suspension" design marked the next step in furnace construction (Fig. 7). It differed from the Purves type in being entirely curvilinear and of uniform thickness throughout its length, and, compared with the Fox, the ridges were narrower and stronger, whilst the valleys were wider. Under cold water tests it is of greater strength than either; and, when in use in a boiler, it has proved its ability to withstand an increasing accumulation of deposit, for a longer period of time, before the metal becomes so weakened by overheating as to be incapable of resisting the steam pressure.

Suspension Furnace

The applicability of the term "suspension" to this type of furnace is due to the following circumstances. A furnace collapses only when there is a sufficient amount of deposit on the water side to cause the metal to become practically red-hot. The first part of the wall in a suspension furnace to become overheated would undoubtedly be the valley, as the ridge is sheltered from the heat; and, being approximately in the form of a catenary longitudinally, this plastic metal, on being unduly stressed, receives immediate and direct support from the ridges by the transmission, throughout the entire valley to the ridges, of a practically simple tensile stress. The metal is, therefore, uniformly in a state of tension between the points of support—a condition which can only be designated as "suspension."

It follows that the essence of successful furnace design lies in the correct adjustment of the dimensions and curvatures of the inward and outward corrugations, so as to effect the best possible compromise between the ideal forms of theory and practice, which, as it happens, are to some extent in conflict.

In the original suspension design, the circular arcs forming the valleys are tangential to the arcs forming the ridges, the ridges being in fact formed by the ultimate intersection of the extensions of the valleys, with the sharp apices suitably rounded off (Fig. 8). The value of the long suspended valley has been fully demonstrated in practice, and the strength-controlling influence of the narrow ridge is definite, so that a combination which results in greater ultimate resistance to collapse also marks an advance in the art of furnace manufacture.

A construction embodying such a combination results, if the valley is of such a radius that the ultimate intersection of the arcs is below the apex of the ridge, the ridge being, as it were, an independent element or girder, from which the valleys are suspended and into which their sides are merged (Fig. 9). The metal forming the sides of the ridges is, therefore, disposed in planes practically normal to the axis of the furnace, with easy curves at all points where the metal undergoes a change of direction. This apparently simple modification was the result of very exhaustive tests extending over a long period; and although the change of form would seem on casual inspection to be unimportant, the resulting disposition of the metal is so effective that, when tested by hydraulic pressure, its resistance at the point of collapse is within ten per cent. of the elastic limit (Fig. 10). When in use in a boiler, its superior resistance to deformation will be even more marked, because not only is the strength of the outward

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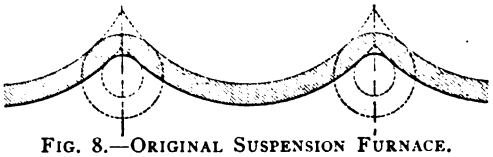

FIG. 8.—ORIGINAL SUSPENSION FURNACE.

FIG. 9.—IMPROVED SUSPENSION FURNACE.

corrugations or circumferential girders greatly increased, but the intervening metal is so curved as to retain, practically unimpaired, the stress-distributing and simplifying effects of the suspension principle, whereby the strength of the ridges is effectively utilized to reinforce the resistance of the inward corrugations to local deformation by overheating.

Causes of Failure of Furnaces

A FURNACE is often very severely strained, and is liable to slight deformation, if the tubes are too close to the crown, or if the furnace is otherwise too rigidly stayed. A furnace is subjected to very great variations of temperature, and is consequently always tending to lengthen or shorten, so that, if by faulty design it is not allowed breathing facilities, it will either leak at the landings or alter its shape. Furnace fire-bars should not be fitted in tightly when cold, for obvious reasons. Assuming that attention is given to these points, and that shortness of water does not occur, a furnace collapses only when its wall becomes heated to redness through either oily deposit or excessive scale, so that the safest furnace is the one which will longest withstand the conditions of severe usage, before the metal in any portion of its wall becomes weakened through overheating, and which, having become overheated, will retain its shape for the longest period of time before collapsing. If a furnace of any recognized type is covered with water and is reasonably clean, it will never collapse, as in that condition its resistance is five times greater than the load brought upon it by the steam pressure; but this margin commences to disappear when the temperature of the metal reaches 650° F., and vanishes when the metal becomes red-hot.

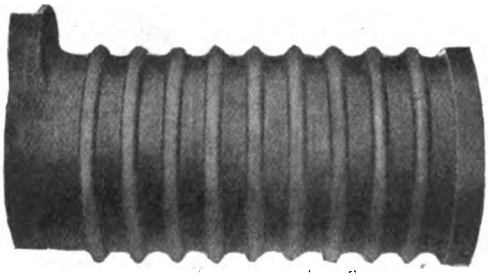

FIG. 10.—MORISON'S SUSPENSION FURNACE.

It is only at these extreme temperatures that the capacity of any particular form of furnace to resist collapse becomes effective and apparent, so that the only true measure of the comparative working strength values of different furnace formations lies in their respective resistances to collapse when at the temperature of plasticity. The temperature of steam at 200 lbs. is 380° F.; the temperature at which steel commences to lose its tensile strength is 650° F., and at 1,200 degrees about 75 per cent. of its original strength has disappeared. If the surface of a furnace in a boiler for, say 200 lbs. pressure, were clean, the temperature of the metal would never reach the point at which its original tensile strength would be appreciably reduced, even under very high rates of evaporation. If, however, the surface were simply rubbed over with a very thin coating of mineral oil, the temperature would at once rise to over 650° F., even with a moderate rate of evaporation. An appreciation of this fact will explain many a so-called mysterious collapse of furnaces in apparently clean boilers. If a mere coating of oil of inappreciable thickness will raise the temperature of the metal beyond the safe limit, it follows that an extremely thin scale or deposit, containing a high percentage of oil, must inevitably result in dangerous overheating.

Electric Ignition Timing

SINCE the introduction of electric ignition for petrol motors it has been found necessary, in order to obtain satisfactory results, to alter the point of ignition to suit variation in engine speed. Many attempts have been made to render this timing automatic, but up to the present none of these has proved satisfactory. To appreciate the difficulties involved it is necessary to consider all the causes that render variation necessary. It is found that as an engine runs faster the point of sparking has to be advanced, so as to cause it to occur earlier, and when an engine is running very fast it is necessary for the theoretical point of ignition to be even as early as 110° of crank travel before the firing centre.

The principal reason for this is the interval of time between the first ignition of the gas

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and the instant when maximum pressure is reached; this interval, being approximately constant, renders it necessary to advance the point of ignition as the engine speed increases, if it is desired to keep the point of maximum pressure at the beginning of the working stroke. Two other causes add to this effect—the lag of the trembler on the induction coil, and the lessened compression at high speeds due to the loss of volumetric efficiency which is caused by the wire drawing effect of both induction and exhaust valves. These are slightly compensated for by the quicker burning of the richer mixture taken in at high speeds, caused by the increased vacuum in the jet chamber. It is evident that the coil lag is a time element, and that the interval between the completion of the electric circuit and the "break," due to the downward movement of the trembler, will be constant for the same coil, and quite independent of the engine speed. This factor is of less importance since the general adoption of high-speed tremblers, and is, of course, entirely absent in magneto ignition. The loss of volumetric efficiency results in more burnt gas being left in the cylinder from the previous explosion, and the taking in of a lessened charge, causing a drop in the compression and consequent slower burning, as the degree of compression has considerable influence on the rate of burning of an explosive mixture of given quality. The enriching of the mixture at high speeds compensates for this to a certain extent, depending on the efficiency of the valve gear and carburettor, but, of course, this compensation is only at the sacrifice of fuel efficiency.

From the foregoing remarks it will be evident that if the mixture is throttled, thus lowering the compression, it will be necessary to advance the spark to obtain a correct diagram at the same engine speed; and this effect will generally be intensified, as throttling usually results in a weakened mixture. Any automatic device must, therefore, not only vary the contact to compensate for variation of engine speed, but, if correct ignition and maximum efficiency is desired, also for varying degrees of throttling and alterations of quality of mixture.

Fig. 11 shows approximately the theoretical points of completing the electric circuit for different cases, but it must be remembered that the spark in the cylinder does not occur until an appreciable time after the completion of the primary circuit.

Induction Valves

THE mechanically-operated induction valve has now almost entirely superseded the atmospheric valve for petrol motors. The atmospheric valve is exceedingly simple, but is rather noisy in its action, and is not so efficient at high speeds as the mechanically-operated valve. The spring tension on the valve must be as light as possible to avoid throttling the charge, the usual tension allowed being about 1¼ lbs. per square inch of valve area. The lift allowed is usually only about one-tenth the diameter of the valve, so as to enable it to close quickly; thus a plain valve has to be about twice the diameter of the mixture pipe to give the necessary area of opening.

An advance upon this was the three-ported valve; this was really three small valves in one box, and evidently gave a larger area of opening for the same lift, and consequently a higher volumetric efficiency, especially as the small valves could be lighter and more sensitively sprung. The three-ported valve cannot be conveniently operated mechanically, and as a mechanical valve can be controlled by as strong a spring as thought desirable, the lift was generally increased to about one-seventh the diameter of the valve, rendering any other aid to volumetric efficiency unnecessary. Recently, with the introduction of engines having larger cylinders, it was found advisable to keep the induction valves as small as possible, and at the same time to obtain a high volumetric efficiency without an excessive lift to the valve, as an excessive lift is found to prevent the engine running so well at high speeds. The solution is the multi-ported valve. If properly arranged this

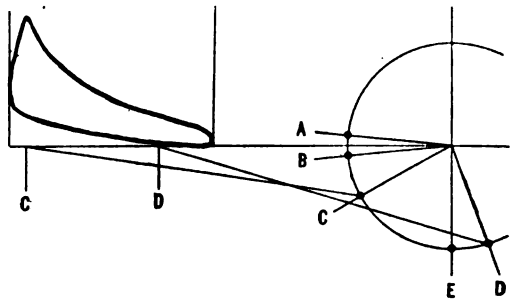

FIG. 11.—TO ILLUSTRATE POSITIONS OF IGNITION UNDER VARIOUS CONDITIONS.

A. *Point of ignition for hand starting.*
B. *Point of ignition for very slow running.*
C. *Point of ignition for full load at about 400 r.p.m.*
D. *Point of ignition for full load at about 1,200 r.p.m.*
E. *Approximate point of ignition for very light load at about 400 r.p.m.*

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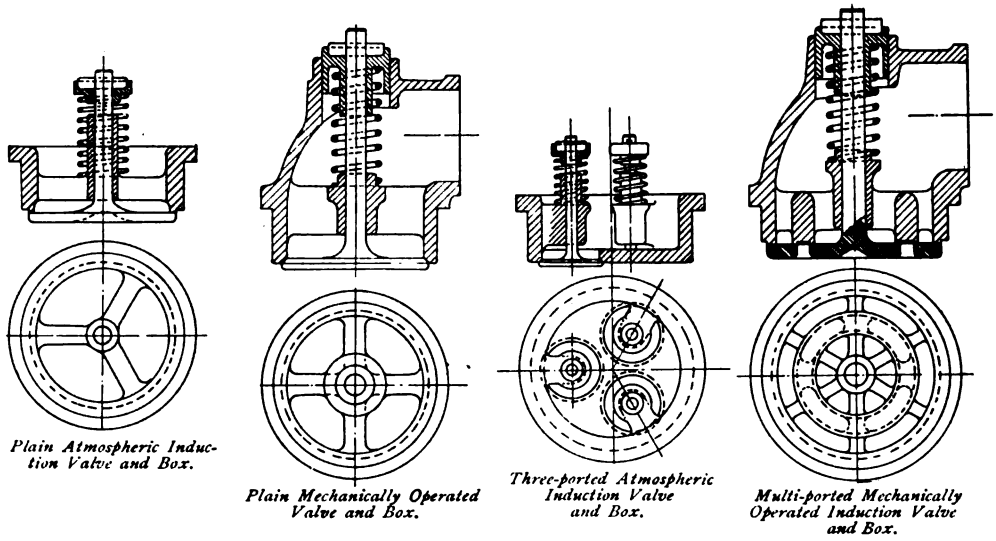
Plain Atmospheric Induction Valve and Box.
Plain Mechanically Operated Valve and Box.
Three-ported Atmospheric Induction Valve and Box.
Multi-ported Mechanically Operated Induction Valve and Box.

FIG. 12.—FOUR TYPES OF INDUCTION VALVE.

type of valve will give an increase of opening for the same lift of 30 per cent.

Fig. 12 shows these four types of valve, together with their boxes, as usually constructed. The valves are steel forgings, and the boxes are made of cast-iron.

The Marconi Patents in America

IN the action for infringement of patent rights recently instituted in the United States by the Marconi Company, against the De Forest Wireless Telegraph Company, and tried before Judge Townsend, the result, as might have been anticipated, was partly in favour of the Marconi Company, but will probably not prevent the De Forest Company from using their system. As a matter of fact, both companies claim to have secured a complete victory; but as the most general claim of the Marconi Company has been disallowed, the De Forest Company have every cause to be satisfied. An article published in the *Electrician* for May 5, 1905, gives a short *resumé* of the decision of Judge Townsend. The exact contribution of Marconi is thus summarised:—

"Maxwell and Crookes promulgated the theory of electrical oscillations by means of a disruptive discharge; Hertz produced these oscillations and described their characteristics; Lodge and Popoff devised apparatus limited to lecture or local experiments or to some impracticable purposes, such as the observation of thunderstorms. Marconi discovered the possibility of making these disclosures available by transforming these oscillations into definite signals, and, availing himself of the means then at hand, combined the abandoned and laboratory apparatus, and by successive experiments reorganised and adapted and developed them into a complete system capable of commercially utilising his discovery. Therefore, if a later inventor, by the exercise of a discriminating faculty, detects and distinguishes the difficulties, and estimates their proportions, and breaks down the barrier, or bridges the interval, or stretches beyond the limitation, by an instrumentality which, in the very facts of its construction and operation, and by the adaptation of its mechanism to the end sought, suggests original and creative design, then, by his contribution of the essential idea in tangible shape, he had invented a new instrumentality, and his monopoly should be sustained.

"While the De Forest detector was held not to be the equivalent of the 'tube containing metallic powder' of claims 8 and 10, the judge found that it was equivalent to the imperfect electrical contact of claims 1, 3, and 5. With regard to claim 1, however, it is pointed out that this is a new broad claim introduced into the re-issued patent, and, in view of the limitations imposed upon the Marconi coherer by the publications of Branly, Popoff, and Lodge, such a generic claim, much broader than appeared in the original patent, for which it appears to have been substituted, is not permitted, as the effect would be to enlarge the scope of the original invention."

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BALLISTICS OF MODERN RIFLES.

PART IV.—INTERNAL AND EXTERNAL BALLISTICS.

Continued from No. 17, p. 407.

By R. H. HOUSMAN, B.Sc., M.I.E.E.

Caps.

THE work required of the cap in igniting a charge of smokeless powder is much more onerous than in a black powder cartridge.

With gelatinised nitro-powders, the surface, being very smooth and dense, requires the application of a high temperature for a certain length of time before ignition occurs. Within certain limits it seems probable that the time and temperature may be varied inversely to produce satisfactory ignition. For example, with "Mark I" cordite it is found that better results are given by caps containing a large quantity of composition, with a small percentage of fulminate of mercury and a large percentage of sulphide of antimony. This gives a low temperature flame of considerable duration. A composition of this nature seems to be less liable to produce violent oscillations of pressure than a smaller charge of composition containing a large percentage of fulminate of mercury. It is found that the quantity of composition contained in the cap must bear a certain proportion to the net volume of the cartridge case, in order to secure prompt ignition. This is equivalent to saying that the cap must produce a certain gas pressure, in order that the powder may instantly ignite over its whole surface. Experience shows that a cap may exert sufficient pressure to expel the bullet from the cartridge case, and yet not fire the explosive. It is just possible that in such cases a very small amount of the explosive commences to burn and is then extinguished, since the whole surface of the cordite is found blackened by the firing of the cap. This may sound improbable to those who have not experimented in this direction; but, nevertheless, the extinction of cordite which has ignited certainly does occur in some places. For example, a long case 0·303 was fired in a short-chambered gun, so that a quarter of an inch at the head was unsupported; the result was that the case was burst close to the head, but no great damage was done, the greater part of the cordite being found unconsumed in the case.

Recoil.

Recoil is measured in the first instance as momentum—that is to say, as the product of mass and velocity (lbs. ft./sec.), or by the product of pressure and time (lbs. secs.), these being independent of the weight of the gun or the constraints imposed upon it. The recoil is most satisfactorily measured by converting the gun itself into a ballistic pendulum. The momentum is then proportional to the chord of the angle of the swing. The actual effect of recoil on the firer does not appear to be proportional to the momentum, but to the energy which is transmitted from the butt of the gun to the shoulder of the firer. This energy depends, first, upon the weight of the gun; and, secondly, on the firmness with which it is held to the shoulder, since it is obvious that the velocity of recoil is less when the shoulder is, so to speak, incorporated with the stock of the gun, than when the gun is freely suspended. The energy of a freely suspended gun is easily calculated from the momentum, by dividing the latter (in lbs. ft./sec.) by the weight of the gun; this gives the maximum velocity of recoil. The square of this velocity, multiplied by the weight of the gun and divided by 64, gives the energy of the recoil in ft. lbs. For example, if the momentum of recoil is found to be 100, and the weight of the gun is 10 lbs., then the maximum velocity of recoil is 10 ft. per second. The energy of recoil will be 10×10^2, divided by 64—*i.e.*, about 15·6 ft. lbs. It is clear that the energy of recoil corresponding to a given momentum is inversely as the weight of the gun. Experiments show that the momentum of recoil is considerably greater than that of the projectile at the muzzle, the difference being due to the momentum of the gases which follow the bullet. By dividing the difference between the momentum of the gun and projectile by the weight of the charge of powder, we obtain the equivalent velocity of the escaping gases. It is, of course, highly probable that the whole of the

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TABLE V.—BALLISTICS OF 0·303 RIFLE WITH VARIOUS BULLETS GIVING EQUAL MUZZLE ENERGIES.

RANGE.	VELOCITY. Feet per second.			TIME in Seconds.		
Yards.	197 grains.	215 grains.	235 grains.	197 grains.	215 grains.	235 grains.
	feet/seconds.	feet/seconds.	feet/seconds.	seconds.	seconds.	seconds.
0	2,400	2,300	2,200	0·0	0·0	0·0
100	2,161	2,091	2,021	0·1317	0·1368	0·1424
200	1,956	1,911	1,863	0·2781	0·2876	0·2968
300	1,774	1,749	1,714	0·4389	0·4492	0·4656
400	1,604	1,593	1,575	0·6177	0·6316	0·6478
500	1,447	1,449	1,444	0·8140	0·829	0·8465
600	1,305	1,318	1,324	1·033	1·047	1·064
700	1,186	1,206	1,219	1·273	1·284	1·301
800	1,086	1,111	1,129	1·540	1·543	1·558
900	1,018	1,038	1,056	1·825	1·826	1·832
1,000	966	988	1,006	2·126	2·120	2·125
1,100	918	942	963	2·451	2·437	2·428
1,200	876	901	923	2·78	2·760	2·75
1,300	837	863	887	3·13	3·112	3·078
1,400	801	823	853	3·50	3·468	3·425
1,500	767	796	822	3·89	3·826	3·781
1,600	735	765	792	4·29	4·216	4·161
1,700	705	736	764	4·70	4·615	4·548
1,800	676	708	738	5·135	5·033	4·938
1,900	649	682	712	5·57	5·468	5·359
2,000	621	656	687	6·06	5·901	5·791

TABLE VI.—BALLISTICS OF 0·303 RIFLE WITH VARIOUS BULLETS GIVING EQUAL MUZZLE MOMENTA.

RANGE.	VELOCITY. Feet per second.			TIME. Seconds.		
Yards.	197 grains.	215 grains.	235 grains.	197 grains.	215 grains.	235 grains.
	feet/seconds.	feet/seconds.	feet/seconds.	seconds.	seconds.	seconds.
0	2,500	2,300	2,100	0·0	0·0	0·0
100	2,257	2,091	1,934	0·126	0·1368	0·1489
200	2,037	1,911	1,782	0·266	0·2876	0·310
300	1,848	1,749	1,639	0·421	0·4492	0·4853
400	1,673	1,593	1,504	0·592	0·6316	0·6764
500	1,511	1,449	1,378	0·780	0·829	0·880
600	1,362	1,318	1,266	0·989	1·047	1·112
700	1,233	1,206	1,170	1·221	1·284	1·358
800	1,125	1,111	1,088	1·476	1·543	1·624
900	1,042	1,038	1,028	1·755	1·826	1·909
1,000	994	988	983	2·009	2·120	2·207
1,100	937	942	942	2·367	2·437	2·517
1,200	893	901	904	2·692	2·760	2·842
1,300	852	863	869	3·042	3·112	3·181
1,400	815	823	836	3·402	3·468	3·54
1,500	781	796	806	3·773	3·826	3·904
1,600	748	765	778	4·172	4·216	4·275
1,700	718	736	751	4·57	4·615	4·664
1,800	688	708	724	5·002	5·033	5·085
1,900	659	682	699	5·455	5·468	5·504
2,000	632	656	675	5·915	5·901	5·935

gas does not escape at the same velocity; but the effect on recoil is the same as if it all did escape at the equivalent velocity thus calculated. This velocity is in the neighbourhood of 4,000 ft. per second, the exact figure depending upon the temperature of the gases at the moment when the bullet leaves the muzzle. It is found that with cordite the momentum due to the gases varies from 25 per cent. to 33 per cent. of the momentum of the bullet. It is difficult to say what is the maximum recoil permissible for a military rifle. The Martini-Henri, with black powder, gave a bullet velocity of about 1,350 ft./sec., and had a momentum of recoil of about 125 lbs. ft./sec. Taking the weight of the rifle at 9 lbs., this

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gives a velocity of recoil of about 13·9 ft. per second, the energy of recoil being about 27 ft. lbs. It may be noticed that this is just about the same as the energy of recoil of a 12-bore sporting gun, weighing 7 lbs., and using smokeless powder cartridges. This amount of recoil has been found to be uncomfortably great for shooting at a target, although not noticeable when shooting at game. The momentum of recoil may be reduced below 100, even with the highest ballistics at present attainable in a 0·303 rifle. There should, therefore, be no objection to increased ballistics on the score of recoil. The 0·303 bullet, weighing 215 grains, will give a momentum of recoil of 100 for a muzzle velocity of about 2,500 ft. per second. Taking the weight of the rifle at 9 lbs., this gives an energy of recoil of about 17½ ft. lbs., which is trifling compared with the 27 ft. lbs. of the sporting gun and the Martini-Henri rifle.

External Ballistics.

Best Weight of Bullet for Military Rifles.

The ranging power of a bullet depends mainly on its "sectional density" (or its weight divided by the square of its diameter) and its initial velocity. Most military bullets have a "sectional density" of about 0·32, the weight of the bullet being measured in lbs., and the bore in inches. The best value for the "sectional density," however, depends entirely on the range at which it will be most used. The greater the "sectional density" the longer the range at which the bullet will be effective; but, for a given velocity, both pressure and recoil increase with the weight of the bullet. If the maximum range can be definitely stated, it is possible to determine the weight of bullet which will give the flattest trajectory, either (*a*) for a given maximum pressure, or (*b*) for a given recoil.

Table V. shows the effect of increasing and decreasing the weight of the 0·303 bullet by 10 per cent., at the same time varying the velocity so as to give equal muzzle energies —that is to say, equal maximum pressures; Table VI. gives similar data for equal momenta, or the same recoil. It will be seen from Table V., with bullets of 197, 215, and 235 grains, at 2,400, 2,300, and 2,200 ft./sec. respectively, that the velocities of all three bullets are equal at about 500 yards, so that the lighter bullet has always been travelling the fastest, and has, therefore, the flattest trajectory. This advantage is gradually lost as the range increases, until at about 1,000 yards the times of flight of all three bullets are equal—that is to say, all three bullets will have dropped about the same distance below the position that they would have occupied if gravity had been non-existent. This is equivalent to saying that the angles of elevation required for all three bullets are about equal at 1,000 yards. For all shorter distances the lighter bullet will require a less angle of elevation than the heavier ones. It thus appears that if the ballistics are limited by the strength of the breech action, as in the Service 0·303 rifle, a bullet weighing 197 grains will require less elevation for ranges up to 1,000 yards, than either the Service or heavier bullets, owing to the higher velocity attained. Beyond 1,000 yards the heavier bullets will have the advantage. The advantage of the light bullet is still more marked if we consider the ballistics as limited by recoil, since, for the same recoil, the velocity of the 197-grain bullet may be increased to 2,500 ft./sec., as compared with 2,300 for the 215 grain, and 2,100 ft./sec. for the 235-grain projectile. In this case the three velocities are practically equal between 1,000 and 1,100 yards, whilst the times of flight are about equal at 2,000 yards. This shows that the 197-grain bullet, with 2,500 ft. per second velocity, requires less elevation up to 2,000 yards than either the Service bullet at 2,300 ft. per second, or the 235-grain bullet at 2,100 ft. per second. Of course, if all three bullets had the same initial velocity, the advantage would lie with the heaviest bullet at all ranges.

The point that it is necessary to bear in mind is, that so long as the ballistics are limited either by the pressure which the breech action will stand, or the recoil which the soldier can endure, it does not follow that the heaviest bullet is the best; the great advantage of flat trajectory over the first 1,000 yards or so may possibly make the adoption of lighter bullets advisable. It may be mentioned that very fine shooting has been made at long ranges with 200-grain bullets out of the 0·303 rifle. The adoption of a 200-grain bullet in 0·303 barrel, with flat strip M.D. cordite in the long case previously described, would make possible a muzzle velocity of 2,700 ft./sec., with an energy of recoil of about 17½ ft. lbs., and a pressure of 22 tons per square inch. It is hardly necessary to say that this would give us a military weapon immensely superior to anything at present in use, without any great increase in the bulk of the cartridge, the only essential being a sounder breech action than that of the present Service rifle.

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THE THEORY AND PRACTICE OF STEAM GENERATION.

PART III.—THE STEAM-RAISING PLANT.

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By JOHN B. C. KERSHAW, F.I.C.

INTRODUCTION.

IN the first two articles of this series* the author has dealt with the "Raw materials of Steam Generation," namely, water, coal and air, and with the "Theory of Steam-raising." In this article he proposes to describe the various types of boiler and furnace, and the methods of producing draft for carrying on the combustion process. In the past the combustion of solid fuel in the furnace of a boiler, and the production of steam by aid of the heat generated in the furnace, have been considered very simple operations, unworthy of the close attention of chief engineers or of the need of highly skilled labour. The custom thus became general of neglecting the boiler-house, and of employing in it only the cheapest form of unskilled labour; in fact, the engineers or managers of large manufactories regarded this portion of the plant as a dirty disagreeable place, to which it was unnecessary for them to devote much time or attention, and looked upon any man who could handle a shovel and throw coal upon a fire as sufficiently skilled for the work of firing the boilers. The writer was chemist and under-manager at a large factory twenty years ago, and writes with personal knowledge on this subject.

Although this attitude towards the boiler plant is slowly changing, there are still too many works in this country in which the steam-generating plant is grossly neglected, and is left in charge of men whose only qualification for the work is that of physical strength. A higher rate of pay is required to cure this latter evil, and not until it has been generally recognised that the charge of a boiler plant requires brains as well as strength will the class of men firing boilers be raised to the high level of intelligence really demanded by their work. To feed a fire with solid fuel, so as to produce a maximum of steam and a minimum of smoke, demands considerable knowledge and practical ability. It is simply absurd to expect this in men paid at the rate of 24*s.* per week—a rate which does not attract the class of men required. A good fireman would be cheap at 36*s.* or 40*s.* per week. As a well-known writer on boiler management has pointed out, a fireman will handle forty to sixty tons of fuel in the course of a week, and can easily waste or save many times the value of his weekly wage *in fuel alone*. Had the policy of paying well for this work been adopted fifteen years ago, there would have been less need of, and less scope for, the numerous mechanical devices for performing the actual firing work of furnaces. These mechanical stoking appliances are no doubt successful to a certain extent, and yield far better results than were obtained under the old régime where boilers were fired by mere labourers dignified with the name of "stokers"; but it is generally admitted, after fifteen years' experience of these devices, that a skilled and really competent fireman is the equal of, if not superior to, the best of the mechanical stoking appliances. The mistake of putting cheap labour in charge of these appliances was also made in the early days of their use; and much of the early dissatisfaction and troublesome breakdowns experienced with mechanical stoking appliances, when these were first introduced, was due to the mistaken notion that as any fool who could handle a shovel was good enough for a fireman, so any man who could handle a spanner and called himself an engineer was competent to take charge of a mechanical stoking plant.

However, these mistakes of early days are now being slowly remedied, and works' managers have learned by painful experience, that even an automatic stoking plant requires highly-skilled attention and management by an experienced engineer, if good results are to be obtained from it. The comparative efficiency of hand labour and of mechanical stoking will be dealt with again in the next article of this series; but in this article description of a few of the best known forms of mechanical stoker will be given in the section devoted to furnace construction.

The section devoted to boilers is neces-

* See April and May issues of TECHNICS.

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sarily somewhat condensed, and only a few of the leading types of shell and water-tube boilers are described. No attempt is made to decide between the rival claims of Lancashire and water-tube boilers for steam-raising purposes, and it must be recognised that each type has advantages for special demands, which makes the decision dependent upon the peculiar conditions of the work or industry.

Draft.

Chimney and Fan Draft.—As pointed out in Article I. of this series, an adequate supply of dry, and preferably heated air, under perfect control, is an essential condition for the economical conduct of the combustion process. In the past this has been most usually obtained by aid of tall chimneys—a system which is miscalled one of "natural draft." Chimney draft is, however, not very satisfactory for many reasons, and in modern boiler plants chimneys are being displaced by fans, with benefit to the economical working and scientific control of the plant.

Chimney Draft is really dependent upon the difference between the weight of the column of heated air within the chimney and that of an equal column of air outside it; this is a function of the difference between the temperatures inside and outside the chimney. If the exit gases be cooled below a certain temperature, the draft ceases to be sufficient for the combustion process.

In Article II. it was shown that with exit gases containing 10 per cent. of CO_2, and at a temperature of 465° F., about 2,380 B.Th. units of heat escape for every pound of fuel burnt under the boilers. The loss represented by these units is the running cost of obtaining the chimney draft, for 465° F. is the minimum temperature with which chimneys can be worked. With fuel testing 13,500 B.Th. units, and costing 7*s.* 6*d.* per ton delivered in the bunkers, the cost of natural draft works out to (2,380/14,500) × (7*s.* 6*d.*), or 15·8*d.* per ton of fuel burnt under the boilers. It may be objected that this calculation is somewhat unfair to chimney draft, because the percentage of CO_2 is rather low, and denotes much excess of air passing up the chimney. There are few boiler-plants, however, in which the average CO_2 contents of the chimney gases are in excess of this figure; and even taking the best possible case in which 15·2 per cent. of CO_2 is present in the exit gases, the loss of heat units is still 16·2 × 400 × 0·25 = 1620 B.Th. units, equal to 12 per cent. of the value of the fuel, which in the case under consideration represents 10·8*d.* per ton of fuel burnt.

It is therefore a mistake to assume that chimney draft costs nothing beyond the interest on the capital expended in erecting the chimney, and that as compared with fan-draft it can show great economy in running costs. A minimum expenditure of 10*d.* per ton of fuel burnt is necessary to maintain the chimney gases at a temperature which will produce the requisite draft at the boiler furnaces. In most boiler-plants this minimum cost of maintaining the draft is greatly exceeded.

As regards the calculation of the effective draft, in inches of water, produced by a chimney with exit gases at a definite temperature, the following formula is one of many which have been published for this purpose:—

$$d = h\left(\frac{7{\cdot}6}{a} - \frac{7{\cdot}9}{b}\right)$$

in which d = draft in inches of water.
h = height of chimney in feet.
a = absolute temperature of the external air, in degrees F. $(t + 460)$.
b = absolute temperature of the gases in the chimney in degrees F. $(t' + 460)$.

With chimney gases at 600° F., and the external air at 60° F., the last part of the expression gives a factor of 0·007, and the formula then becomes

$$d = h \times 0{\cdot}007.$$

Using this formula, we obtain the following figures for the draft in inches of water for chimneys of various heights:—

Height of Chimney in feet.	Suction at Base of Chimney in inches of water, with exit gases at 600° F.
50	0·35
75	0·525
100	0·700
150	1·050
200	1·400
250	1·750
300	2·100

The effective draft at the boiler furnace is always 35 per cent. to 40 per cent. less than the suction at the base of the chimney, and depends upon the length and area of the intervening flues, and the state of the brickwork as regards leakage. The effective draft at the chimney base, as given in the above table, is also dependent upon the state of the

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atmosphere, and is much greater in dry clear weather than in a damp foggy atmosphere.

As regards the draft required to burn completely ordinary solid fuel, this varies from 0·40 to 1·5 inches, and depends upon the character of the fuel and its state of division. Large lump bituminous coal demands the least draft, and very fine anthracite or South Wales steam coal the greatest draft. The usual plan is, to erect a chimney of sufficient height and area to give the maximum draft at all times and under all loads, and to use dampers to adjust the draft to the needs of each boiler and furnace. This method has many drawbacks, and lacks the adaptability of the fan-draft system. It is partly for this reason that chimneys are now passing out of favour.

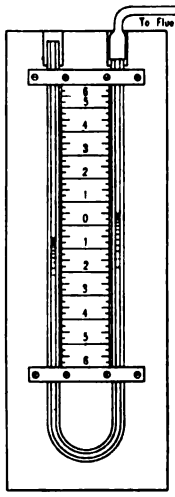

FIG. 1.—GAUGE FOR MEASURING SUCTION IN FLUE.

However, the managers of most works already provided with tall chimneys of adequate power are unlikely to cease using them as long as they stand. It may be pointed out here that much can be done (by attention to the design, tightness, and repair of the damper holes, brickwork and flue manholes) to render chimneys more efficient as draft-creating agencies. Draft gauges of the type shown in Fig. 1 should be installed at the chimney base, and at several points in the flue system; any unusual drop in the draft between the chimney base and the boilers should at once receive attention, since this will doubtless be due to unnecessary air leakage and faulty brickwork. The flues of boilers that are out of use for cleaning or repair should also be stopped off with iron shields or brickwork, since no boiler dampers are absolutely tight, and much air creeps into the flues through boilers that are not being worked.

As regards the draft required within the furnace of a boiler, in order to obtain proper combustion of the fuel, Hiller, in his handbook on the *Working of Steam Boilers*, states that high efficiency can be obtained with 0·30 inch behind the bridge, and 0·45 inch in the main flue at the back of the boiler; but it is better to have some reserve of draft power, and to be able to produce, when desired, 0·50 inch in the furnaces, and 0·65 or 0·70 inch in the main flue.

A fixed draft gauge ought to be attached to every boiler furnace, in order that the fireman may know exactly the state of his draft and the conditions of his fire without opening the furnace doors. Draft gauges (of the steam pressure gauge type) can now be obtained for this purpose, with the face-dial marked in inches of water or in pounds.

Fig. 2 shows the form of water-gauge adapted to measuring the speed of the exit gases, a very finely divided scale and inclined tube being employed in this case.

Fan-Draft.—The chief advantage of fan-draft—namely, that it renders the engineer in charge of a boiler plant independent of the state of the atmosphere and direction of the wind, and enables him to meet satisfactorily any sudden demand on the boilers for steam—has already been alluded to. The further advantages are: that it requires less capital outlay than chimney stacks and the costly foundations for the same, since short steel columns of 50 or 75 feet in height serve to carry off the products of combustion; that the losses of heat with the exit gases are reduced, since these can be cooled to 60° F. if desired, with improvement instead of damage to the draft; and, finally, that more scientific control of the draft and of the whole combustion process is possible, owing to the fact that the draft can be easily altered to suit the character of the fuel being burnt. Extensions of the plant, and of the steam-raising capacity of the boilers, are also more easily carried out when fan-draft is installed, since the installation of a second or third fan is a comparatively simple under-

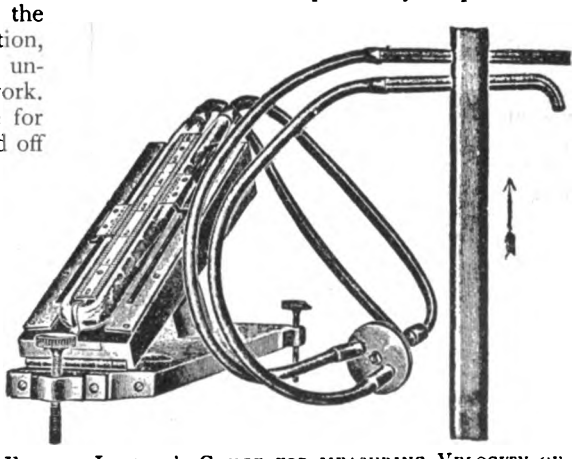

FIG. 2.—JACKSON'S GAUGE FOR MEASURING VELOCITY OF FLUE GASES.

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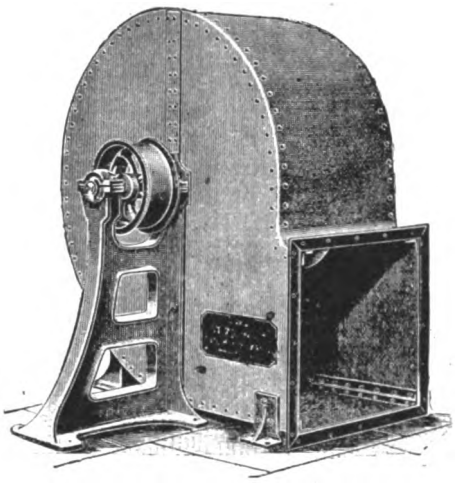

FIG. 3.—"CYCLONE" FAN, FOR BELT DRIVING.

taking. Fig. 3 shows the size and general appearance of one of the fans for producing draft, and Fig. 4 shows a fan in course of installation.

Fan-draft may be applied to work boilers upon either the *forced* or *induced* draft system. In the former, the fan is placed towards the front or underneath the boilers, and the ashpits of the furnaces are closed in. In the latter system, the fan is placed at the base of the chimney, or to the rear of the boiler-plant, and the ashpits of the boiler-furnaces are of the usual type. Each system has its advantages and disadvantages, and the local conditions must be studied carefully, in order to decide which is the better in any particular case. Where the fan is placed at the foot of the chimney or at the rear of the boilers, and is employed to create induced draft, the losses by air leakage through the brickwork and damper holes may be as heavy as with chimney draft. Thus the induced draft system of working boilers demands more care with regard to the brickwork and settings than the forced draft system. Fig. 5 is from a photograph of the boiler-plant at the newly-erected Neepsend Power Station at Sheffield, where the Ellis and Eaves induced draft system, with a preheated air supply, has been installed. The fan is seen to the rear of the boilers; the flues carrying this pre-heated air to the boiler fires run midway round the sides of the boilers, as shown. At this works the excellent plan has been adopted of reducing air leakage to a minimum by casing the boilers in glazed brickwork, and the writer has little doubt that in time this plan will become general in all well-built plants.

Another method of producing "forced" draft, and one that has been widely adopted, is that of using steam-jets in place of a fan. This method cannot be recommended, and when the scientific principles of combustion are better understood the use of steam-jets for promoting draft will only be adopted in exceptional cases, when no other method is available.

In the first place, a steam-jet requires far more steam than is generally recognised; in some cases where a whole battery of boilers is worked on this principle, from 5 per cent. to 10 per cent. of the steam generated is being employed to create the forced draft. An efficient fan-draft can, on the other hand, be worked with much less power than is represented by this quantity of steam. Further, steam is not a desirable constituent of the air blown into the furnaces of a boiler, for the reasons stated in Article II. of this series, any benefit derived from the presence of hydrogen in the furnace gases is more than counterbalanced by the energy required to bring about the original dissociation of the molecules of water into their constituent

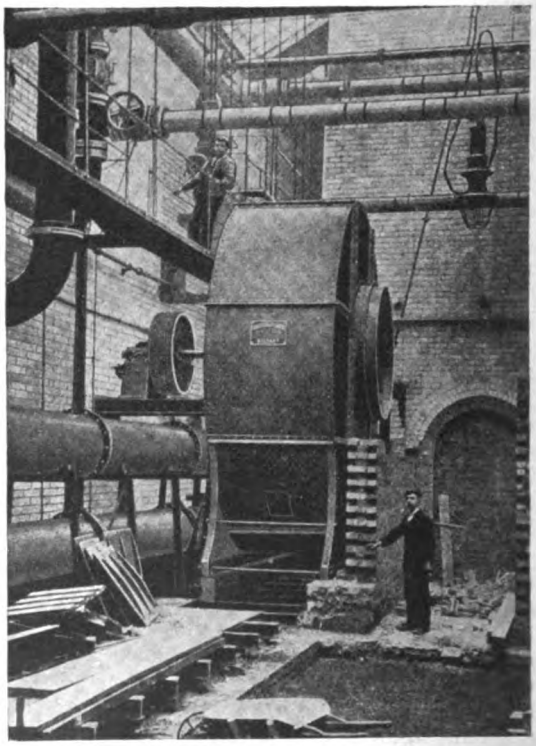

FIG 4.—"SIROCCO" FAN IN COURSE OF INSTALLATION.

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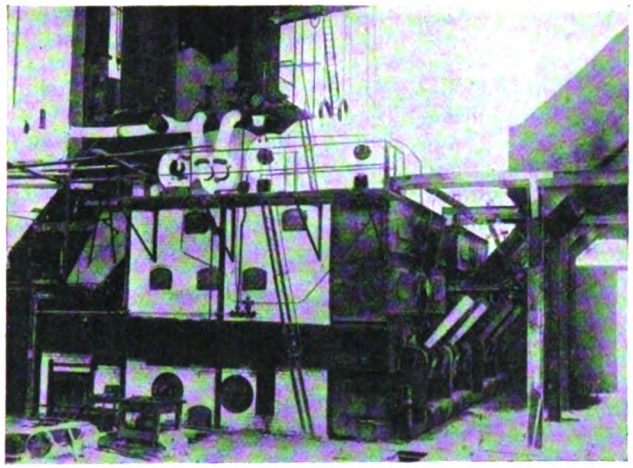

FIG. 5.—HOT AIR AND INDUCED DRAFT PLANT, NEEPSEND POWER STATION, SHEFFIELD.

atoms, and by the high specific heat of the aqueous vapour carried away in the exit gases. The specific heat of dry air is 0·237, of Co_2 0·216, while that of steam is 0·475. These figures alone indicate the unwisdom of blowing large quantities of steam into the furnaces of the boilers, since each pound of steam carries off twice as much heat as the same weight of dry air. *This heat is absolutely lost unless the furnace gases are reduced below 212°F.* before they leave the boiler or economiser plant, and unless the steam is condensed in the form of water with liberation of its latent heat. It is well-known, however, that not one boiler-plant in a hundred passes the exit gases away with their temperature reduced to 212°F. Therefore, under present conditions of working, steam-jets are wasteful in two directions, and their use is inconsistent with the economical and scientific working of the steam-raising plant.

THE BOILER.

The characteristic essential to a good boiler is that it shall produce a maximum quantity of *dry steam* at the expense of a minimum quantity of fuel. It should also possess some reserve of steaming power over and above that required by the normal demands upon it. To possess these qualifications it is necessary that the following points should have consideration in the design and setting of the boiler:—

(*a*). The plates or tubes which are in contact with the fuel or flame and heated gases, on the one side, and with the water on the other, should be of ample superficial area, and should be so arranged that their periodic inspection for corrosion or flaws is a comparatively simple matter.

(*b*). The combustion chamber of the boiler should be adapted to the fuel burnt, and the heated gases should not be allowed to come into contact with the water-cooled tubes or plates, before perfect combustion has been attained. This principle will be discussed further under "Furnaces."

(*c*). All portions of the heating surface exposed to the hot fuel or gases should be covered with water, and the removal of scale from these surfaces should be undertaken at regular intervals, the frequency of which will depend upon the hardness of the water employed in the boilers. As pointed out in Article II., a *clean* boiler plate *when covered with water* in free circulation cannot become over-heated or damaged, excepting by the highest of furnace temperatures; but when coated with scale or with oily deposits, over-heating is nearly certain to occur even with low furnace temperatures.

(*d*). The free circulation of water in the boiler should be allowed for in the design, or should be promoted by some artificial arrangement (as by a steam-jet) at certain dead points. The use of small model boilers

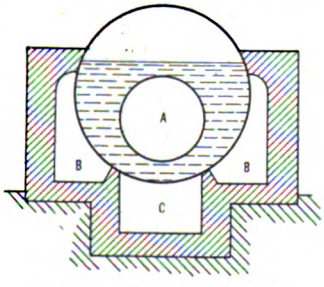

FIG. 6.—CORNISH BOILER.

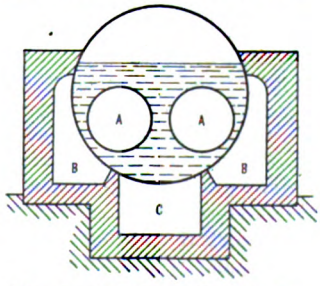

FIG. 7.—LANCASHIRE BOILER.

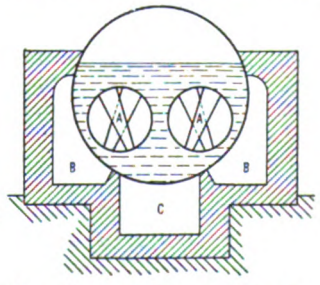

FIG. 8.—LANCASHIRE BOILER, WITH WATER TUBES.

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of glass, in order to discover these dead points, is to be recommended.

(*e*). The side flues of the boiler should be designed so that removal of the flue dust is possible, without any serious check to the boiler working. Most boiler settings are defective in this respect; when burning poor coal, high in ash contents, frequent stoppages are required to remove the accumulated dust from the side flues, or these are allowed to become choked up, and the effective draft is allowed to fall away to one-half that required to obtain proper combustion of the fuel in the furnace of the boiler.

A few of the leading types of boiler in use in this country will now be briefly described.

Fig. 6 is a cross-section of the oldest—or Cornish boiler. The furnace is formed by the front end of the large central fire tube A, and is thus within the boiler. The hot gases travel back to the front by the side flues B, B, and away to the main exit flue, by the bottom flue C. A few of these boilers are still to be found in this country, but they have mostly been displaced by the two-flued or Lancashire boiler, and by the many varieties of the water-tube boiler.

The Lancashire Boiler is shown in cross-section in Fig. 7. In its main features it resembles the Cornish boiler, but it possesses two central fire tubes A, A, and therefore two furnaces in place of one; the gases travel back to the chimney by the bottom flue C. The Lancashire boiler is the most popular type in this country, and when well-designed and constructed, and when fired with a suitable fuel, it is a very efficient steam-raising apparatus. The length of furnace and provision of the secondary air supply requires careful adaptation to the fuel burnt.

A mistaken attempt was made in the sixties to improve the steam-raising capacity of the Lancashire boiler by placing a number of cross water tubes in the two central fire tubes, right in the path of the flame and hot gases. These were intended to improve the circulation of the water in the boiler and also to increase the heating surface of the plates exposed to the hot gases. Fig. 8 is a cross-section of this boiler. It had a brief period of popularity, but is now going out of favour again, since the cross tubes in the central flues reduce the draft, increase the tendency to produce smoke, and are not really needed to promote circulation of the water in the boiler.

Other types of shell boilers are the Scotch marine boiler, the dry-back boiler, and the locomotive fire-tube boiler; but limits of space will not permit a detailed description of these to be given.

Another type of boiler, in which the water is circulated between two or more shells or drums, by means of a very large number of tubes which are directly exposed to the flame and hot gases, has become very popular in recent years, and is known as the *water-tube boiler*. The chief advantage of this boiler, as compared with the Lancashire boiler, is that it contains comparatively little water, and that steam can be very rapidly generated, either when starting-up with all cold, or when a sudden demand for steam is made upon it in the ordinary course of working. A large number of varieties of this type of boiler have been designed and patented, but only two of these can be dealt with here. Fig. 9 represents the inclined tube type, made by Messrs. Babcock & Wilcox, and Fig. 12 is a diagrammatic elevation of the same, unessential details being omitted. It will be seen from Fig. 12 that the water travels from the back E to the front end F of the large horizontal drum, through the large number of inclined water tubes, and that the gases from the furnace A are made to pass in a zig-zag manner among these tubes to the exit passage into the main flue at G. In order to avoid undue stress, and also to lessen the chances of air leakage through the brickwork, the boiler is suspended by tie bolts and slings, from steel columns shown in Fig. 9;

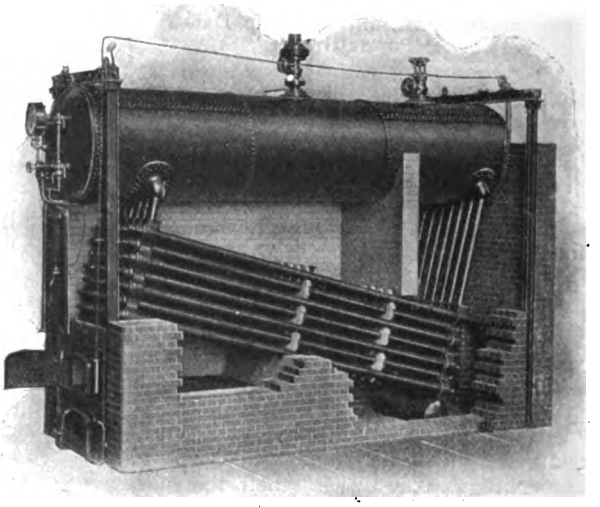

FIG. 9.—BABCOCK & WILCOX WATER-TUBE BOILER.

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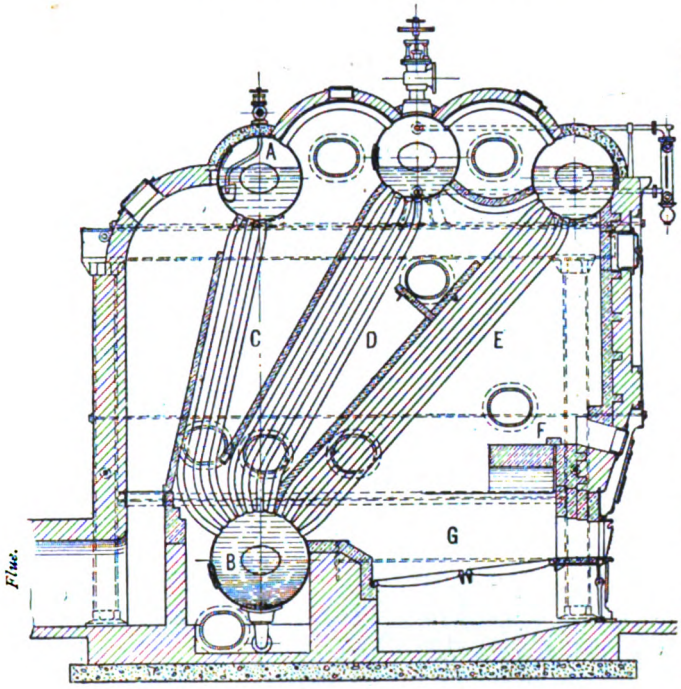

FIG. 10.—STIRLING WATER-TUBE BOILER.

the brickwork casing is built up around it, after it has been accurately fixed in position.

Fig. 10 shows a water-tube boiler of the vertical tube type in sectional elevation, made by the Stirling Water-Tube Boiler Company. In this type of boiler the drums are either four or five in number, and the tubes are much more inclined than in the Babcock and Wilcox type. The water drums are also smaller, and are placed parallel to the furnace and boiler front. The two back rows of tubes C and D serve chiefly for pre-heating the water, and most of the steam-making occurs in the front tubes E which rise directly above the furnace. The flame and gases travel in a zig-zag manner through the three sets of tubes, and arrive at the drop-flue at the back portion of the boiler setting at a comparatively low temperature. The water for the boiler is fed into the back top drum A, and sediment and scale collect in the bottom drum B. It is claimed for this type of boiler, that there is less danger of the tubes becoming coated internally with scale, than in the other types in which the tubes are placed more horizontally. The furnace G of this type of boiler is covered for two-thirds of its length by a fire-brick arch F, which assists in promoting combustion of the fuel.

Furnaces.—There are three essential conditions requisite for the perfect combustion of solid fuel, and these can only be attained if the furnace of the boiler is well designed, and permits of proper regulation and control of the air supply.

The three essentials of good combustion which must be maintained in the furnace of the boiler are :—

1. A sufficiency of air, but not an excess of the same.
2. A sufficiently high temperature.
3. A perfect admixture of the air and volatile hydrocarbons.

In order to obtain the first of these conditions with furnaces which are hand-fired, there ought to be some arrangement for varying the air supply at different stages of the combustion process ; for a furnace which has just been charged with solid fuel requires more air above the fire-bars than one which contains only the glowing coke and cinders left after the volatile gases have been distilled and have passed away from the furnace.

Fig. 11 shows the usual type of furnace of a Lancashire boiler, intended for hand-firing. The fuel rests on the fire-bars B, B, B, and air enters partly by the slits in the fire-door A, and partly by the ash-pit D. In some cases a slit is provided in the bridge wall C, and a further supply of air enters by this passage. When heated to a high temperature this "secondary" air supply, as it is called, is a great aid to perfect combustion.

The great defects of this furnace, however, are, that in its usual form there is too little control of the air supply. As usually worked, it leads to the use of a large excess of air, and, in consequence, to a large loss of heat

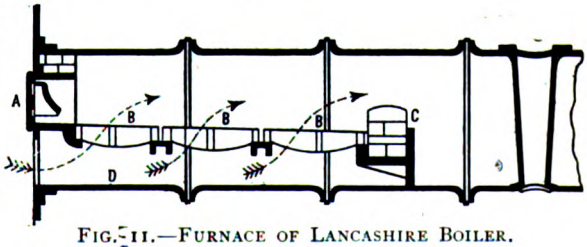

FIG. 11.—FURNACE OF LANCASHIRE BOILER.

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in the exit gases. These losses will be discussed in Article V.

If provided with a closed ash-pit, with a bridge air-supply also under control, and with a mechanical device for automatically closing the slides in the furnace door after the volatile gases have been distilled off each charge of fuel, this furnace is capable of giving excellent results with hand-firing.

The length and grate area of the furnace, however, require adapting to the variety of fuel used, and it is too often assumed that no alterations in these are required when changing to a new variety of fuel.

When a fuel containing 30 per cent. and over of volatile matter is employed with this type of furnace, the use of a fire-brick lining to the furnace and to the flue for a short distance beyond the bridge, will lessen the danger of smoke production, and improve the efficiency of the combustion process.

Fig. 12 shows the usual type of furnace used for hand-firing with water-tube boilers. The furnace A is enclosed by brickwork, and possesses a closed-in ash-pit B, the air admission above and below the fire-bars being regulated by slides in the doors C and D. In some respects this furnace is an improvement upon the furnace employed for Lancashire boilers, but it has the grave defect that the products of combustion, after leaving the grate, directly impinge upon the lower banks of water-tubes, and this contact with masses of relatively cold metal reduces the temperature, and arrests or hinders combustion. In other words, this type of furnace ignores the condition (2) essential to perfect combustion, *viz.*, that of temperature. Bituminous fuels, containing 30 per cent. or over of volatile matter cannot, in fact, be burned in this form of furnace without the production of smoke. Details of the modifications which have been introduced, in order to remedy this defect, will be given in Article IV.

When mechanical stokers are employed, the design of the furnace and regulation of the combustion process becomes much simplified; for there is no intermittent opening of the furnace doors at frequent intervals of time. These stoking appliances feed the fuel into the furnaces, either continuously or in small amounts, at very short intervals, without any air admission beyond that required for combustion; and there is no sudden liberation of large volumes of hydro-carbon gas, such as occurs with hand-firing.

Figs. 13, 14 and 15 show two very common types of mechanical stoking appliances and furnaces; the first two represent the chain-grate stoker, usually employed with the Babcock & Wilcox water-tube boilers; Fig. 15 is a diagrammatic section of the Vicar's coking mechanical stoker.

In the chain-grate stoker (Figs. 13 and 14) the fuel is fed from a hopper on to a travelling bed, which carries it gradually forward under a fire-brick arch, and into the centre of the combustion chamber. If the speed of the travel of the grate and the feed of fuel be properly regulated, all the volatile gases are distilled off before the glowing fuel passes the fire-brick arch, and all the solid carbon is burnt out of the residue, before the remaining cinder and ash reach the end of the travel of the grate, and are forced over the bridge, shown in Fig. 14, into the ash-pit.

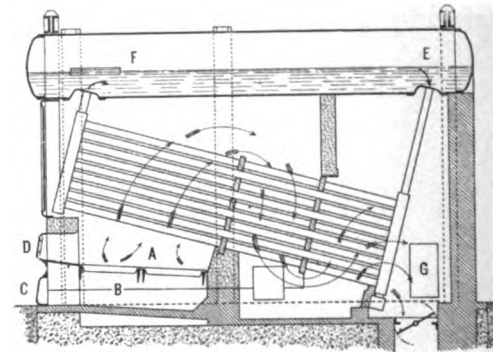

FIG. 12.—SECTION OF BABCOCK & WILCOX WATER-TUBE BOILER AND FURNACE.

In theory, the chain-grate stoker is excellent; but in practice it has the defect that it is most difficult to regulate the speed of travel of the grate and feed of fuel, so that all the carbon is consumed without production of bare spaces and admission of excess of air. Also there is a tendency amongst its users to curtail the arch and to allow the half-burnt gases to pass upwards too soon into the banks of water-cooled tubes.

Fig. 15 is a diagrammatic section of Vicar's coking stoker, as applied to a Lancashire boiler. The fuel is fed from a hopper A on to a dead-plate E by means of a ram B, and here the volatile hydro-carbons are distilled off. The half-coked fuel C is then carried forwards on to the centre of the furnace D, where the coking operation is completed, by means of moving fire-bars, which move forwards all together, but return in alternate groups. Under proper conditions of work only little unconsumed carbon finds

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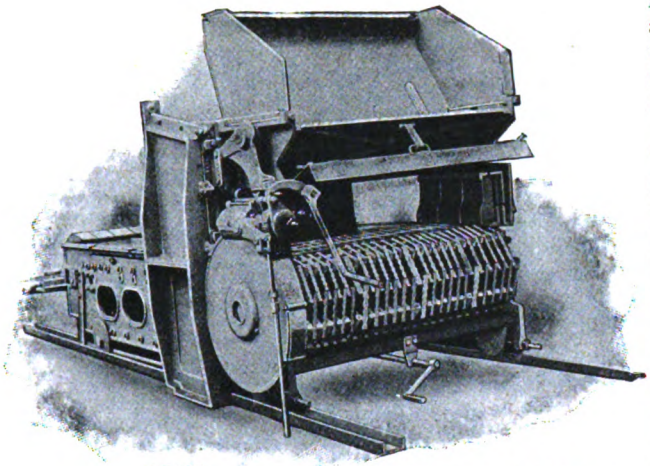

FIG. 13.—BABCOCK & WILCOX MECHANICAL STOKER.
Front view, showing hopper. Fire doors open.

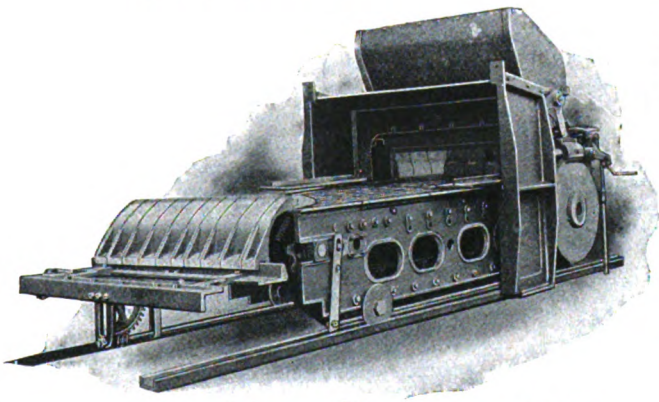

FIG. 14.—BABCOCK & WILCOX MECHANICAL STOKER.
View inside Furnace, showing bridge.

its way into the heap of ashes at F, and with suitable fuels and under capable management this type of stoker is said to give excellent results.

It is evident, however, from the diagram, that the half-burnt gases are allowed to come into contact much too soon with the water-cooled boiler-plates, and that a fire-brick arch extending three-fourths of the length of the furnace is required, in order to prevent too early loss of heat, and retardation of the combustion process. The open ash-pit is also a weak feature of this stoking appliance, since under bad conditions of work much air-leakage may occur.

Limit of space will not permit of any detailed description of the other very numerous types of mechanical stoker now in use in this country for firing steam boilers.

They may be divided into three classes, of which the "coking" and the "underfeed" stokers are, in the writer's opinion, the more satisfactory; nevertheless, stokers of the "sprinkling" type have enjoyed a considerable spell of popularity. When allied with well-designed furnaces, built with proper provision for prevention of air-leakage, and for maintenance of the temperature requisite for perfect combustion of the hydro-

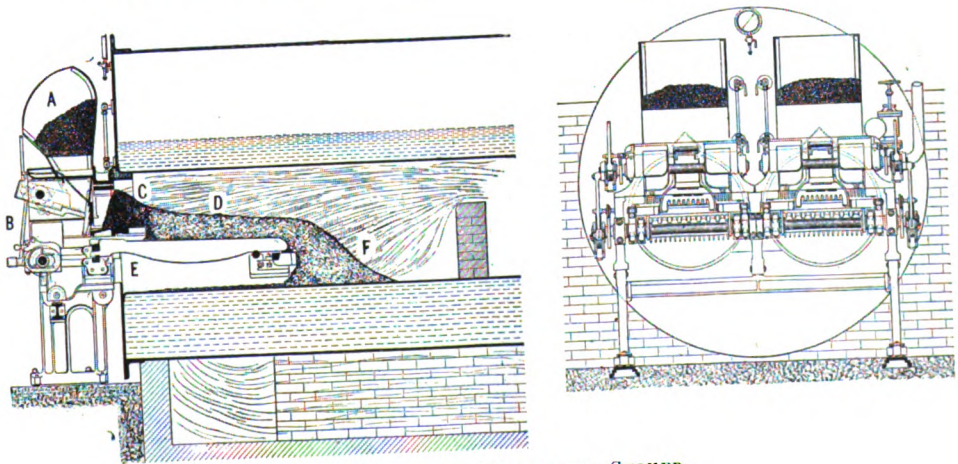

FIG. 15.—VICAR'S MECHANICAL STOKER.

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carbon gases, good results can be attained with almost any one of these types; and the writer is not, therefore, inclined to judge between them. The wear and tear of mechanical stoking appliances, however, are considerable, and the maintenance charges for these plants are heavier than their makers are often ready to admit. The human stoker, therefore, is to be preferred, excepting for very large boiler installations, in which the whole of the coal and ash-conveying plant is controlled by machine power. If the fireman adds intelligence and skilled experience in the management of the combustion process to physical strength, the present writer believes that he will be able to obtain evaporative results with any fuel, equal to, if not better than, those obtained with even the best of the mechanical stoking appliances.

(*To be continued.*)

PHOSPHORUS PRODUCTION IN THE ELECTRIC FURNACE.

IT is not generally known that the electric furnace is being employed to an increasing extent for the manufacture of phosphorus, and that, in the opinion of those best qualified to judge, the whole of the phosphorus production of the world will, in time, be carried on by the electric furnace method. The advantages offered by electricity in this manufacture are, first, that a cheaper raw material can be employed; second, that the heating of this material is more under control and that therefore the distillation of the phosphorus is more regular; and, third, that the product obtained in the condenser is cleaner, and worth a higher price, before refining.

Phosphorus was prepared by Scheele, in 1769, from powdered bones, in which it is present as calcium phosphate. The method he devised for preparing it from this raw material has been in use, with slight modifications, down to the commencement of the present century. The bones were first roasted, and then powdered and heated with sulphuric acid; the solution of calcium hydrogen phosphate obtained in this way was then evaporated to the consistency of thick paste, and heated to a high temperature with powdered charcoal in clay retorts. A mixture of phosphorus vapour and carbon monoxide distilled over, under these conditions, and the former was condensed under water, as a yellow wax-like substance. The crude phosphorus thus obtained requires re-distillation.

The great difficulty with the old method of production was to obtain retorts which would stand the combined action of the heat and the sulphuric acid, and in most cases the losses due to breakage and to gaseous diffusion through the walls of the retorts were very large.

The electric furnace methods of production, on the other hand, dispense with the use of sulphuric acid, and are based upon a reaction which occurs when the bones mixed with sand (silicic acid) and charcoal are heated to a very high temperature in a suitable retort. Under these conditions the silicic acid combines with the calcium to form calcium silicate, and the phosphorus distils over with carbon monoxide gas as before. This method of production was discovered by Wöhler, and has been known for many years, but it could not be used upon an industrial scale until the advent of the electric furnace, since the temperature required to bring about the reaction is much above that attainable with clay retorts and the usual methods of external heating. The phosphorus, in fact, does not commence to distil over until a temperature of 1150° C. is reached, and the distillation is complete only between 1400° and 1500° C.

Internal electric heating is necessary to attain this temperature, and in Germany, where already one-third of the output is obtained by the new process, gas-tight iron cylinders, lined with fire-clay, and carbon electrodes inside these retorts, are employed for carrying on the manufacture. The process is a continuous one, since the molten calcium silicate can be run off from the bottom of the furnace while the raw materials are fed in intermittently or continuously at the top. The chief precaution necessary in working this process is to maintain the temperature of the upper part of the furnace and its delivery pipe above the boiling point of phosphorus (290° C.), as otherwise stoppages of the pipes and explosions may occur.

In this country Messrs. Allwright and Wilson, of Birmingham, are the only manufacturers of phosphorus, and they are believed to be using an electric furnace—a process very similar to that described above.

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THE FIBROUS CONSTITUENTS OF PAPER.

By CLAYTON BEADLE.

Illustrated with photo-micrographs by Monsieur Marcel Rostaing.

WE may with advantage here introduce the subject of rosin sizing, as the papers about to be considered are as a rule not sized with gelatine at all, but only with rosin. The fact that paper could be sized and rendered ink-proof by the addition of rosin was discovered about the year 1800 by M. F. Illig, of Erbach, a watchmaker, who was working as a journeyman in a paper mill at Cröllwitz. In 1806 and 1807 Illig communicated his secret in a pamphlet entitled "Instructions for Sizing Papers in the Pulp after a Sure, Simple, and Cheap Method." He believed that the fibres were embedded in the rosin, and that the sizing qualities were to be attributed to the water-repellent qualities of the rosin. His successors, on the other hand, believed that it was due to the formation of a compound of rosin. Dr. C. Wurster, who thoroughly investigated the subject, proved beyond doubt that the rosin existed in the paper as "free rosin," and that Illig was therefore right in his views; but there are still, to this day, papermakers and papermaking chemists who believe that the sizing is due to a compound of rosin and alumina. It is quite unnecessary in this article to recapitulate the work that has been done on this subject, as students on papermaking can obtain this from the various text-books on papermaking, in detail, if they make use of Hoffmann's "Treatise on Papermaking," published by Sampson, Low. We are only concerned here with any information that may throw fresh light on the subject. The researches about to be described appear at first sight to favour the compound hypothesis, but I think it will be conceded that the probable explanation is, that free rosin is the *real* sizing agent, and not a chemical compound of alumina and rosin. But in order to get the best effect, it is expedient that the softening point should be raised by the presence of bodies such as alumina.

Monsieur Marcel Rostaing's researches, which he has been good enough to communicate to me for the purpose of this article, throw fresh light upon the subject. Rosin size is prepared by boiling rosin with caustic soda or carbonate of soda: it consists essentially of resinate of soda containing free rosin held in suspension. When cold it has somewhat the consistency of soft soap. It is sometimes opaque, sometimes transparent, and sometimes has a streaky mottled appearance, according to the relative proportions of its ingredients. In this condition it is stored. Before using, it is mixed with water at about 120° Fahr., so as to produce a dilute solution of about 3 Tw. The solution is generally milky, due to the presence of free rosin suspended in a very finely-divided state. This "milk of rosin," as it is called, is added to the beating engine; alum is then added, whereby the rosin is precipitated in contact with the pulp. Although rosin alone is the sizing agent, a certain amount of flocculent alumina is precipitated with the rosin, and this becomes mixed with the rosin and entangled with the fibres. Other precipitating agents have been tried, such as sulphuric acid, but it is said to be impossible to get a good sized paper by precipitating the rosin size with sulphuric acid, the reason for which has not been adequately explained.

According to Wurster's published researches, the precipitate obtained by decomposing rosin

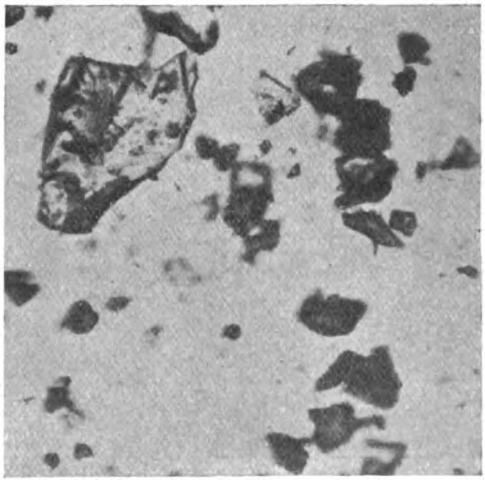

FIG. 1—GROUND ROSIN AS REDUCED TO A POWDER BEFORE BOILING IN SODA FOR CONVERSION INTO ROSIN SIZE.
(*Magnification*, 180 *diameters.*)

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size with sulphuric acid is coarse and compact, and less waterproof than when the size is precipitated by alum. Compare Figs. 2 and 3, which appear to indicate that this is the case. Might this not be due to the associated alumina preventing the aggregation of the rosin particles, which latter are free to come together when acid is used? Compare Figs. 1 and 2, the former showing particles of rosin ground to a powder before conversion into rosin size, the latter after precipitation in a hydrated flocculent condition. The former, however finely ground, are no good for sizing the pulp. Rostaing's researches show that the melting point of a precipitate obtained by precipitating the rosin size by sulphuric acid is lower than that of the commercially ground rosin from which the rosin size had been prepared, the figures being as follows:—

	Melting Point.
Rosin precipitated by sulphuric acid	91° C.
Ground rosin	98° C.

This may be due to the fact that commercial rosin is not a pure substance; it contains turpines and other bodies that cannot be precipitated by the addition of an acid. The commercial product has the formula $C_{44}\ H_{62}\ O_4$. The active principle is a substance consisting essentially of abietic anhydride, which after saponification with soda and subsequent precipitation is converted into abietic acid ($C_{44}\ H_{64}\ O_5$). On account of the presence of various foreign

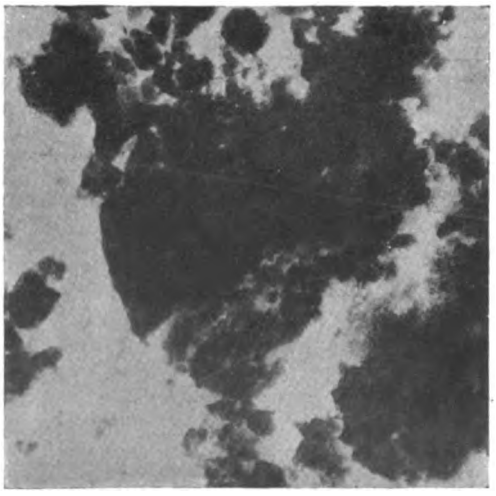

FIG. 2.—PARTICLES OF FLOCCULENT ROSIN PRECIPITATED FROM ROSIN SOAP BY THE ADDITION OF SULPHURIC ACID.
(*Magnification*, 180 *diameters*.)

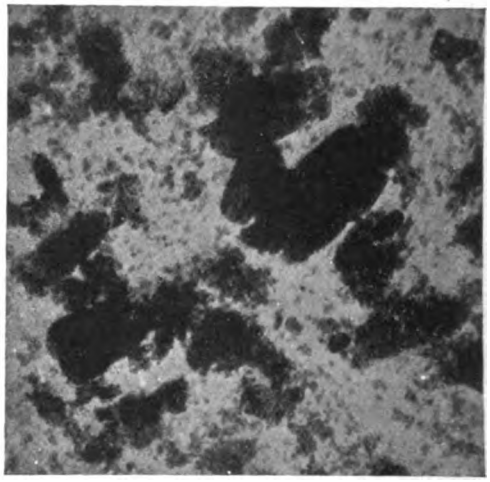

FIG. 3.—PARTICLES OF FLOCCULENT ROSIN PRECIPITATED FROM A SOLUTION OF ROSIN SOAP BY THE ADDITION OF ALUM.
(*Magnification*, 180 *diameters*.)

substances in the original product, it is never constant in composition; but the precipitate obtained from the size can be regarded as fairly constant, except for the presence of more or less alumina, which always accompanies it. I am unable to explain why it is that the melting point of the precipitate is lower than that of the original ground rosin.

It must not be forgotten, however, that rosin will vary anywhere from 98° to 135° F. in melting point. Rostaing suggests that the low melting point of the product precipitated with sulphuric acid may possibly account for the unsatisfactory result obtained. That the melting point of the precipitated rosin is raised in proportion to the amount of alum used to precipitate the rosin is very evident from Rostaing's figures:—

Quantity of Alum per 100 K. of Rosin.	Melting point of the precipitate.
24	190° C.
100	210° C.

It appears to me that this will hold good so long as extra alumina is precipitated along with the rosin. This will only take place so long as there are substances present, such as soda, lime, salts, etc., capable of bringing about this alumina precipitation. I should expect that all alum added in excess of such quantity would not raise the melting point, and would consequently be wasted.

It is worthy of notice that a small proportion (such as 24 per cent.) of alum has had the effect of enormously raising the melting point from 91° to 190° when the sulphuric

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acid and alum precipitates are compared. It is a well-known fact that at about 200° rosin will distil in a current of steam without any appreciable change. When passing over drying cylinders the wet paper is giving off large quantities of steam into the atmosphere, and possibly some of the rosin (if precipitated by sulphuric acid) might be driven off; but the loss can only be slight, and could not account for the inferior results obtained in this instance. As this hypothesis cannot be made to account for the difficulty of using sulphuric acid, the mere difference in the melting points may be made to account for it. If the rosin is too readily melted by contact with the steam cylinder, it may be in too soft and plastic a condition, whilst the paper is being deprived of its moisture under such conditions. The result may be the same as when tub sized papers are dried at too elevated a temperature, the sizing material coating the individual fibres instead of filling up the interstices between these. (See TECHNICS, January number, p. 30.) If the fibres themselves are coated and the interstices are not filled up, the paper does not become inkproof, as the ink is still able to pass through the spaces between the fibres. Rostaing's researches appear to me to point in this direction. The presence of alum or some such infusible material, to mix with and raise the melting point of the rosin sufficiently to prevent the latter from being in too soft a condition as the paper is being dried over the heating cylinders, appears an essential element. On the other hand, I am disposed to think that the precipitate must not be so high in its melting point as to render particles too hard to amalgamate together, otherwise they would hardly fill in the interstices. If too fluid, the microscopic films of rosin are likely to burst, the rosin merely coating the fibres.

FIG. 4.—SOME OF THE PULP TAKEN FROM WIRE, SHOWING PRECIPITATED ROSIN MIXED WITH FIBRES.
(*Magnification, 180 diameters.*)

FIG. 5.—SAMPLE OF PULP TAKEN FROM WIRE, SHOWING PRECIPITATED ROSIN AND STARCH MIXED WITH THE FIBRES.
(*Magnification, 180 diameters.*)

In regard to the quantity of alum necessary for the precipitation of the size, a great deal has already been written. Assuming my theory to be correct, it would remain to be proved what melting point will give the most favourable result. To investigate this it would be necessary to prepare precipitates of different ratios of alumina to rosin, determine their melting and softening points, and observe their sizing effects. As to the amount of alum in everyday practice, so much depends upon the hardness of the water, the basic constituents of the fibres, etc., that no definite rule can be laid down. Rostaing obtained a good-sized paper by using 5 kilos of rosin soap containing 3·37 kilos of rosin per 100 kilos of paper, and for the precipitation of this soap he used 3·5 kilos of sulphate of alumina. That the rosin, precipitate from the rosin size mixed with the pulp, is not precipitated *on* the cell walls of the fibres can be seen by reference to photo-micrographs Figs. 4 and 6. Rostaing came to the same

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conclusion on examining under the microscope an unwashed sample of bleached pulp taken on the wire of the paper machine. The same can be seen by examining the sized pulp taken from the beater. The precipitate is evidently not formed *on* the fibres, but is only mixed with the pulp. Indeed, the edges of the fibres are very clear, and the fibres themselves are very transparent, which could hardly be the case if they were thoroughly coated by a precipitate of flocculent rosin, which is seen by the photo-micrographs Figs. 2 and 3 to be opaque. This view is confirmed on studying a sample of the paper taken after passing over the drying cylinders. It will then be seen that the fibres are darker, and fastened together with a material similar in appearance to a thick cement. (See Fig. 6.) Rostaing's final researches appear to confirm this extremely unorthodox view, particulars of which he has forwarded to me. He has shown that it is possible to obtain a good sized paper by precipitating the rosin not in contact with the pulp in a separate vessel. As far as I know, it has always been held, and I have held strongly to the view myself, that it is a *sine quâ non* that the rosin size should be added to and precipitated in contact with a pulp, and that no result could be obtained by precipitating it in a separate vessel and adding it to the pulp afterwards.

An important economy suggests itself. The method of precipitating out of the beater in a separate vessel might with advantage be resorted to when the water in the engine chest requires a lot of alum to soften and neutralise it (as is often the case). I have before me a sample of paper sized by this method, using per 100 kilos of paper :—

Rosin . . .	3·37 kilos.
Alum . . .	1·70 kilos.

This process further suggests the possibility of supplying a precipitated, hydrated, flocculent rosin or mixture of alumina and rosin to papermakers in lieu of rosin size, so that this precipitated mass could be added direct to the beater without the addition of alum.

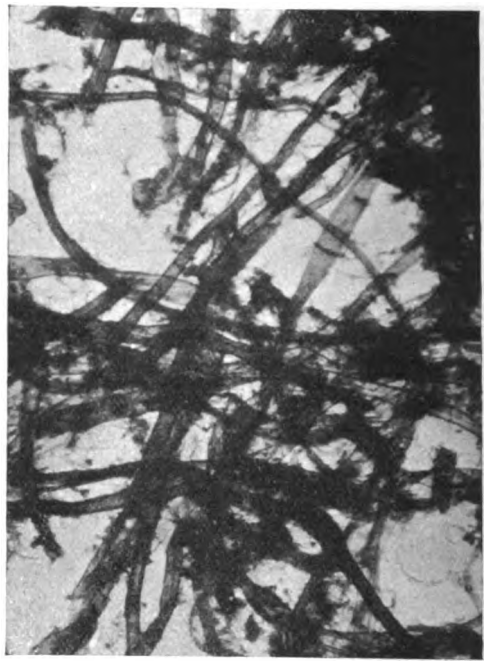

FIG. 6.—SAMPLE OF PAPER, TAKEN AFTER LEAVING DRYING CYLINDERS, SHOWING THE ROSIN SIZE DRIED AND MIXED WITH THE FIBRES.
(*Magnification*, 180 *diameters*.)

I will not claim that these researches lead to final conclusions, but they suggest that the generally accepted views held in regard to the action of rosin sizing are incorrect. Further work on the lines of Rostaing's recent researches should settle this point.

(*To be continued.*)

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COMMERCIAL PHOTOMETRY.

By JOHN F. SIMMANCE, A.M.Inst.C.E., M.I.Mech.E.

THE scientific applications of Photometry are numerous; its practical use is principally confined to the comparison of different methods of artificial lighting, and it is with this aspect alone that the following notes and descriptions deal.

It should be premised that the photometer proper consists, not of any apparatus at all, but only of the eye; for it is the sound and normal eye which alone can judge whether one luminous intensity is greater than another. The unaided eye cannot, however, judge *how much greater* one intensity is than another, and so we require three things:—(1) A standard of known value; (2) a means of comparing the light to be measured with the standard light; and (3) a law derived from experiment. The apparatus (generally called a photometer) designed to meet the requirements specified in (2) will subsequently be referred to as the "photometer head."

THE PHOTOMETRICAL LAW.

The rules governing the measurement of light are very simple; they are included in all text-books of light, and need only be mentioned here.

(*a*) *Kepler's Law of Inverse Squares, viz.:* "The quantity of light falling on a given surface varies inversely as the square of the distance of the surface from the source."

(*b*) *Lambert's Cosine Law, viz.:* "The intensity of illumination received obliquely on a surface is proportional to the cosine of the angle which the luminous rays make with the normal to the illuminated surface."

(*c*) *The Generalised Photometric Law*, compiled from the above, is that

$$e = \frac{I \cos \theta}{d^2},$$

where e denotes the light falling on unit area of a given surface, I is the intensity of the source, θ the angle of incidence of the luminous rays, and d is the distance of the source from the illuminated surface.

The practical application of these laws will be clear from what follows.

Let a standard light of 1 candle, held at 0·5 metre from the photometer head, balance a second light held in the same horizontal plane at 1·0 metre from the photometer head. What are the relative intensities of the lights? The answer is $\frac{(1\cdot0)^2}{(0\cdot5)^2} = 4$, so that the *power* of one source being 1 candle, that of the other is 4 candles. The *intensity* falling on the photometer head is naturally the same in each case, as is seen from the generalised photometric law, $e = (I \cos \theta)/d^2$. In this case the angle which the luminous rays make with the normal to the illuminated surface = 0, and $\cos \theta = 1$.

Thus, taking the standard of light first, the intensity it throws on the photometer head is $\frac{1 \times 1}{0\cdot5} = 4\cdot0$ metre-candles. The intensity thrown on the photometer head by the other light is just the same, for $e = \frac{4 \times 1}{1^2} = 4\cdot0$ metre-candles.

It will be seen from the above that we can accurately test lights which are at an angle to the photometer head if we always arrange that, in taking the readings, the angles which the measured and the standard lights make with the normal to the illuminated surface are equal, for then θ in both cases is the same. This is the reason of the practice, in angle testing, of what is known as "halving the angle."

The Standard of Light of known value.—It is probably accurate to state that there is no such thing as an *absolute* standard of light, so we have to work with some source which is as accurate as possible. The usual standards of light are (1) the English sperm candle; (2) the amyl-acetate lamp; (3) the pentane 10-candle Harcourt lamp; and (4) the Carcel lamp. Table I. gives comparative values and enables other standards to be used, so that results measured in terms of different standards can be reduced to a common basis.

FIG. 1. STANDARD PENTANE LAMP.

The use of these ratios will enable results in, say, hefners to be transposed into candles; but

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TABLE I.—COMPARATIVE VALUES OF DIFFERENT STANDARDS OF LIGHT.

English Standard Candle or Simmance One Candle Standard.	Hefner Lamp.	Carcel.	Simmance Pentane or Methven Two Candle Standard.	Ten Candle Standard.
1	1·14	0·110	0·5	0·1
0·877	1·0	0·096	0·438	0·088
9·1	10·37	1·0	4·55	0·910
2·0	2·48	0·220	1·0	0·2
10·0	11·40	1·10	5·0	1·0

To find the equivalent of any standard, take the line in which the standard used appears, at 1 (under its own heading), and the multiplier for conversion will be found in the same line under the heading of the standard required. Thus, if we wish to see how many hefners a Methven standard equals, look under Methven 1, and in the same line, under Hefner, we find 2·48.

modern photometry requires not only the expression of intensity of sources, but also the expression of light effect or illuminating effect, and to do this we require two things: (1) a unit of lighting power, and (2) a unit of distance. Unfortunately, there is no common international basis for this expression, owing to the use of different units in different countries. In England, and in countries where English units of measurement are used, the unit is a foot-candle—*i.e.*, the illumination, at a distance of one foot, from a standard candle. The illuminating effect (as the light in the streets or on any given surface) is found from the generalised photometric law explained above. Thus a candle held at one foot from a given surface produces an illuminating effect on the surface of one "foot-candle." If it were 0·5 foot away, the effect is $\frac{1}{(0\cdot5)^2}$, or four "foot-candles." If it were two feet away, the effect is $\frac{1}{2^2}$, or $\frac{1}{4}$ "foot-candle."

In Germany, the unit used is a "metre-hefner," or a "lux," although a "metre-candle" is sometimes used. The ratios of the two methods of expressing illuminating effect are as under:—

To convert foot-candles to metre-hefners, multiply by 12·27, since one foot-candle = 12·27 metre-hefners, or luxes.

To convert metre-hefners or luxes to foot-candles, multiply by 0·08147 (or divide by 12·27), since one metre-hefner or lux = 0·08147 foot-candle.

The Photometer Head.—Whatever may be the form of bar or bench used, and whatever may be the standard of light against which a gas-flame or other source of light is to be tested, it is absolutely essential that the comparison part of the modern photometer (or the photometer head) should be capable of use with lights whose colours differ from that of the standard. The most practical arrangement fulfilling these conditions is the Simmance-Abady flicker photometer. A good form of Bunsen disc, a Lummer-Brodhun head, and many other appliances, are perfectly accurate so long as the two lights to be compared are of the same colour; but directly the light to be tested varies from the standard in colour, then great difficulty arises, and the reading becomes only guesswork. This colour difficulty is entirely eliminated by the use of the flicker photometer; and incandescent gas burners, high power lights, arc lamps, and in general luminous sources of any colour or intensity of light can be tested with equal accuracy. The following are points of interest with regard to the photometer:—

This photometer is of the alternating-light type, recently called in France the "scintillation-photometer," but more generally known in America and England as the "flicker." Based upon Newton's experiments, the principle embodied was, about ten years ago,

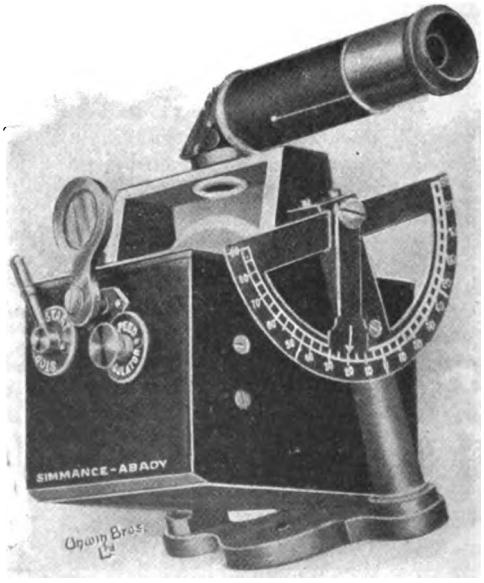

FIG. 2.—PHOTOMETER HEAD, SIMMANCE-ABADY PHOTOMETER.

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studied and utilised in light measurement by Rood, who, however, failed to discover the true lines upon which the Newtonian theory could be reduced to photometrical practice. A very long experience with all the known varieties of the "flicker" photometer, and the construction of many others of different patterns, resulted in the design of the present instrument, which is most sensitive to degrees of lights of the same colour, and also enables the intensities of the most violently contrasted tints to be compared and balanced.

The rules to be observed are as follows: The light effects must be in juxtaposition without any apparent division line, and must move, oscillate, or rotate so that the point of juncture of the two illuminated surfaces passes and returns entirely across the vision-field. Any hiatus, or longer exhibition of one light than the other, biases the result. The observation surface or surfaces upon which the light rays fall must be at exactly the same distance from the eye, at exactly the same angle in relation to the line of sight, and must be of pure white, such as is afforded, for example, by clean chalk, plaster of paris, magnesium carbonate, or barium sulphate. Any tint affects the accuracy of the result. The observation surfaces must also themselves in turn occupy the field of vision; an "apparent" movement (due to an optical illusion) does not afford accurate results.

The flicker photometer renders possible not only the comparison and measurement of lights of various tints, but also far more delicate and close photometry when the light to be measured is of the same colour as the standard. Thus, a signal green lamp, or an electric arc of high intensity, may be measured with certainty against a Hefner, a Carcel, a pentane lamp, or a standard candle; and the reading between, for instance, two incandescent glow lamps may in a like manner be brought to a very fine degree of accuracy.

Briefly, this instrument does all the work which can be done with an ordinary photometer head, such as a Bunsen disc or Lummer-Brodhun, but with much greater accuracy; in addition, it is the only practical means of estimating coloured lights, etc.

To detail briefly the construction of the Simmance-Abady photometer: It consists of a wheel (Fig. 3) of white material, with a specially-shaped periphery; this wheel is caused to revolve before an eyepiece by means of a suitable motor. At right angles to the line of sight, and parallel with the axis of the revolving wheel, are the two lights undergoing examination; the rays from these fall upon the shaped periphery of the wheel, enabling the effect of each light to be seen in turn through the eye-piece.

Fig. 3 shows the four cardinal positions of the wheel, in sequence, illuminated by two unequal lights. It will be seen how the light effects travel across the line of vision, and alternate as the wheel revolves.

The peculiar shape of the reflecting wheel affords means for using it in ways quite impossible to any other form of colour photometer; it may, for instance, be used to test lights at various angles from the horizontal. Having found the careful cutting of the angles of the wheel to be of so much importance, it necessarily follows that, when lights out of the horizontal are being tested, the box containing the wheel must be carefully turned on its axis, so as to maintain the arranged conditions.

The Photometer Bar.—In using an instrument of precision like the photometer head described, it is obvious that the arrangements of the photometer bench and mounting of the photometer head must be such as to allow of perfect alignment, adjustment, move-

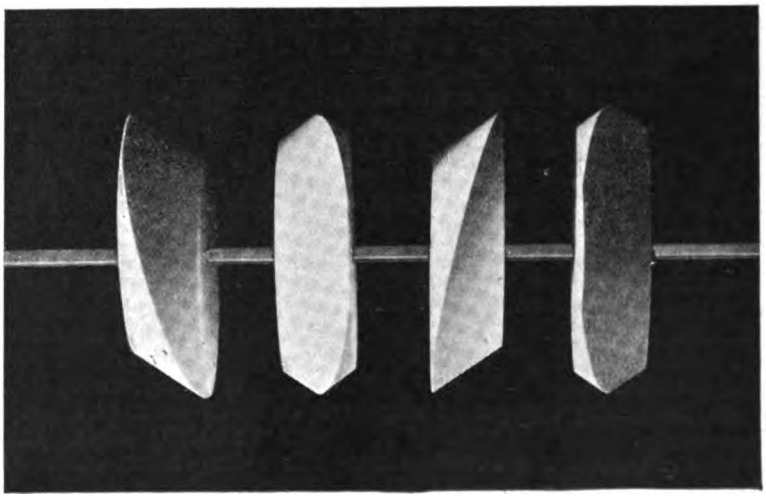

FIG. 3.—FOUR POSITIONS OF WHEEL OF SIMMANCE-ABADY PHOTOMETER.

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ment of the "head" or the light, and of clear and easy reading.

The bar preferentially adopted for general work consists of two steel tubes, 2·54 cm. in diameter, and of such a length that, for ordinary horizontal testing, lights can be placed at two meters apart. The steel tubes are attached to three iron brackets (Fig. 4) with arrangements for levelling, and are enamelled and graduated with white incised divisions, one scale being in centimetres figured from each end, and provided with millimetre verniers, and the other scale being direct reading in terms of unity when the lights are two metres apart. Each carriage has a wide base, and runs on rubber-tyred wheels; while the lights to be tested and the disc box can all be adjusted as to height and brought to perfect alignment. The carriages can be clamped at any position, and will

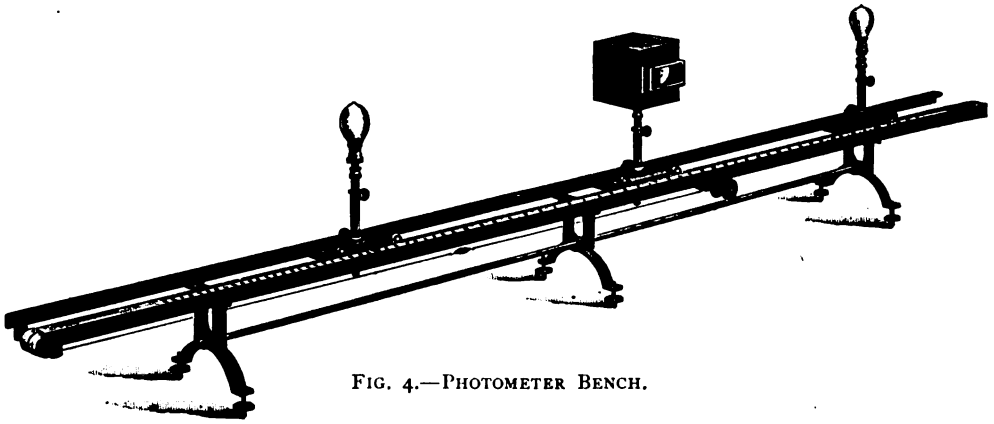

FIG. 4.—PHOTOMETER BENCH.

support a candle balance, a ten-candle Harcourt pentane lamp, and smaller pentane standards, or a Hefner (amyl acetate) lamp. The other carriage will take any kind of gas burner, and is also arranged for leading through wires and fitting a standard lamp-holder for testing electric incandescent lamps. The third carriage takes the photometer head. All three carriages are interchangeable, so that gas or electric current can be led to either of them.

It is impossible to enumerate all the conditions under which it may be desired to use a photometer, so I confine myself to brief but sufficient details.

(*a*) For testing the illuminating power or quality of gas.

(*b*) For testing any gas or electric light horizontally.

(*c*) For testing any gas or electric light at all angles, and obtaining the spherical or hemispherical intensity.

The manipulation of the photometer is the same in all cases; the following instructions must be carefully carried out.

The principal point to be observed in mounting the photometer is that the lights to be measured must be in perfect alignment, vertically and horizontally. The sensitiveness is such that any inequality of angle between the lights and the sighting-box affects the reading, although such differences could not be observed on the less sensitive screens in general use. The necessity for accurate alignment will be fully appreciated when the general photometrical law, $e = (I \cos \theta)/d^2$, is considered in connection with the fact that the Simmance Abady photometer allows variations in e due to very small variations of θ to be visible. A lenticular arrangement is provided in most patterns, for ensuring the accurate adjustment.

The sighting telescope must be adjusted to suit the sight of the operator. A large, clear disc should be observed; that is, the lens must be focussed on the diaphragm. The larger the apparent disc the better, so long as the circumference is sharp and distinct.

Before making tests, wind up the clock. The photometer head is self-contained, no motors or other devices being required. The rotation is commenced by turning the starting knob. This causes each of the light effects to be thrown in rapid alternation through the sighting tube upon the observer's retina. The sighting box must now be moved nearer the lesser light (which is the lesser, is apparent at the first movement), and it will be found that at a certain spot the appearance of flickering ceases, and only a clear, steady disc is observed. This is the point of equality of the lights.

This method of balancing (*i.e.*, the method

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of moving the disc-box) can be varied as hereafter explained.

Greater delicacy of reading is obtained by lessening the speed of rotation by means of the regulator, which also acts as starting-knob. The speed regulator is very sensitive, and a slight turning effects an appreciable alteration in the speed.

For very powerful lights (or for great differences in colour) a quicker movement is desirable. For lights of the same colour, the very slowest speed should be used; the rotation may even be stopped altogether—by holding the hand on the winding key. Thus the two light effects will be seen alternately, alternating more and more slowly until it will be found that the change from rotation to quiescence produces no alteration in the appearance. The ultra-precision obtained by this test will be appreciated by those engaged in scientific research. To obtain this sensitiveness it will be obvious that only a pure white sighting wheel may be used; this should never be touched by hand, and it should always be enclosed carefully after use.

Those operators who have been accustomed only to the rough-and-ready Bunsen disc (excellent as it is for ordinary work) may find the change to the Simmance-Abady photometer irksome, but a little experience and practice will lead them to appreciate its exactitude.

In an account of some tests by this photometer, published in the *British Optical Journal*, April, 1904, it is stated that the sensitiveness was found to be 1 in 1,500, or, roughly, 0·06 of 1 per cent.

It appears quite certain that the relative intensities of two lights, whether of similar or different colours, can be accurately and easily gauged by the method described above. An interesting experiment has recently been conducted by Mr. Roxburgh and Mr. Young, of the Ophthalmic Hospital. Readings upon this photometer were made independently, firstly by Mr. Jacques Abady, who is an experienced photometrist, but suffering from astigmatism; secondly, a gentleman with a pupil dilated by treatment with atropin; thirdly, a patient from the hospital, absolutely colour-blind; and fourthly by the writer, whose sight is considerably impaired, but who has some experience with photometer reading. All the results coincided, and this not only when the lights were of the same white tint, but with red against white, green against white, and green against red. A test of very dark blue against red showed slight discrepancies, owing, probably. to the great obscuration of the light by the blue (almost black) glass; but even these discrepancies were no greater than would probably have occurred when using a Lummer-Brodhun, or a Bunsen disc with lights of the same colour.

The method of reading with this photometer resolves itself into the simple process of deciding whether the disc of light seen through the sighting tube is uniform or flickering. An observer who makes a reading for the first time, when he fully understands that he is required to do no more than this, can read with as great facility and accuracy as an experienced operator; and it is this facility which gives value to an apparatus intended for testing the high intensity lights in vogue at the present time, and also colour effects.

As to the causes of the phenomenon, they, no doubt, are simple on the surface, but may be more complex when closely considered. The pupil of the eye cannot adjust itself to the rapidly-changing intensities, and when the balance is struck, the light, being unchanging and motionless, permits of pupil adjustment. The colours then blend, by persistence of the impression; but should the intensities again change, this retentive sense is dulled by the anxiety of the nerves controlling the pupil orifice to perform their work, an endeavour, however, frustrated by the rapid changing. Professor Hering believes the physiological senses of perception of colour and brightness to be different, the former being possibly present without the latter. In using the photometer, it is suggested that the instrument shall be moved along the bar rather quickly, while the disc is observed through the sighting-glass. The "motionless" point will then be apparent at once, and by a little practice (which in this, like everything else, generates confidence) an operator will swing the disc-box into its balance of intensity without an effort, and without giving the sensitiveness of his retina time to suffer from the numbing effect of the flickerings or throbbing. These conditions point to the possibility of the eyes becoming, under other conditions of stress, unable to appreciate the disappearance of the flicker. Obviously, if fatigue can produce such effects as described, certain conditions of health will act similarly. It may be that a bad liver will produce a constant flicker effect; it is quite certain, however, that no conditions, short of partial or absolute blindness, can prevent the point of equality of intensity being appreciated, although different appearances of the disc may be observed, according to the varying conditions of the retina.

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The Purkinje Effect.—It is submitted, with all deference to the expressed opinions of many of the world's greatest scientists, that the Purkinje phenomenon does not affect the accurate working of the form of flicker photometer shown, if, indeed, it affects any form of alternating photometer. The Purkinje effect may be briefly described in this way:—A right-angled wedge receives upon one face the reddish light from a pentane standard, and on the other the bluish light from an arc lamp; we adjust the relative positions of the arc lamp, the pentane standard and the wedge, until we obtain what we consider is an equal illumination on the two adjacent sides of the wedge. If we now move both these lights to half their original distances from the wedge, we find that the apparent brightnesses of the two surfaces are no longer equal. It is quite clear from this that the retinal sensation of brightness does not increase according to the same law for all colours; the same conclusion may be deduced from the laws due to Fechner and von Helmholtz. It is obvious, therefore, that no unaided eye can judge accurately in photometrical comparisons so long as the disturbing effect of colour is present, unless the distances between the receiving surfaces and the lights are arranged according to some rule which must take the place of that of inverse squares. To put this in another way, it follows that even though an expert photometrist can, with a Bunsen or Lummer-Brodhun apparatus, arrive at what he is certain is a fair balance of the two tints he is comparing, yet grave doubts must exist as to whether the relative candle-powers of the two sources are truly indicated by this balance.

The Purkinje effect is purely a colour effect, and colour does not enter into consideration in the "flicker" photometer. No one would dream of considering a colour-blind person to be affected by the Purkinje law, and yet, as has been shown, such a person can read accurately with this photometer. The experiments made to prove the Purkinje phenomenon have all been carried out with coloured surfaces: never, so far as is generally known, with a scintillation photometer; but conclusive trials have shown that with this instrument, no alterations in distance disturb the true readings. A red light compared with a green at 3 meters gives the same result as when the distance is 2 meters; and an arc light tested against a 10-candle pentane lamp at 40 feet indicates the same candle-power as when the distance is reduced to 15 feet. Thus the question of colour does not interfere with the results.

The accuracy of the photometer for coloured lights is confirmed by the following experiments. Two standard lamps of exactly the same power were used, one at each end of the photometer-bar. A coloured glass screen was interposed, to intercept the rays from one light, which was then measured against the unscreened light. This gave a value for one coloured screen. A second colour was then substituted for the first, and its value measured against the same unscreened light. Thus the following values were obtained:—

(*a*) Unscreened lights.

(*b*) Candle-power of one light screened with one colour.

(*c*) Candle-power of the same light screened with the other colour.

It is obvious, therefore, that one obtained the theoretical ratios of the one light screened with the first colour in terms of the other light screened with the second colour. The one colour was then compared against the other, and the results show almost perfect agreement with the theoretical values. Various initial powers of lights and various lengths of bars were used in these experiments. All the readings on the bar were computed according to the law of inverse squares, and it is clear, therefore, that the absence of "flicker" indicated by the Simmance-Abady photometer gives us a trustworthy means of determining the candle-power of a light, no matter what may be its colour.

(*To be concluded.*)

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NOTES ON SOFTENING AND PURIFICATION OF WATER FOR STEAM RAISING.*

By LOUIS J. LE CLAIR, A.Glas.T.C., A.M.I.E.E.

METHODS of treating hard waters were known many years before Dr. Clark patented his process in 1841, but until comparatively recent years little attention had been directed to the treatment of boiler feed water, in "softeners" for the prevention of scale formation, or in "purifiers" for the elimination of grease from condensation water.

Both scale-forming constituents and grease are most objectionable in feed water, and every effort should be made to reduce the former to a minimum, and to entirely eliminate the latter. Scale reduces the heat-transmitting efficiency of boiler plates, as may be seen by the curve in Fig. 1: the average loss amounts to about 8 per cent. for each one-

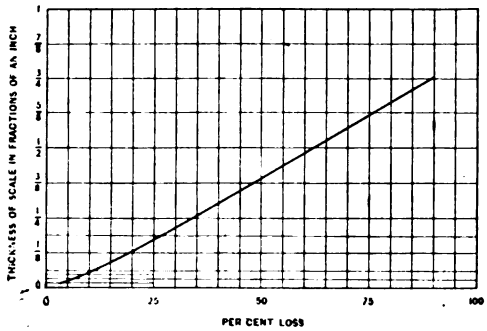

FIG. 1.
Loss of Heating Efficiency due to Scale on Boiler Plates.

sixteenth inch thickness of scale; certain scales, however, resist the transmission more than others, sometimes nearly doubling the above figure. It is also worth remembering, with regard to water-tube boilers, that the formation of scale decreases the internal diameter, and, in consequence, the heating surface of the tubes. In boiler furnaces free from scale and soot the "thermal head" between the surface of the metal next to the fire, and that next to the water is comparatively small. A coating of scale or grease increases this considerably, as may be seen from Fig. 2, which is a diagram of some of Hirsch's experiments, carried out with a clean plate and pure water, and then with coatings of oil and scale. It will be observed that at 45lb. per square foot per hour (for a flame temperature of about 1,500° F.), a com-

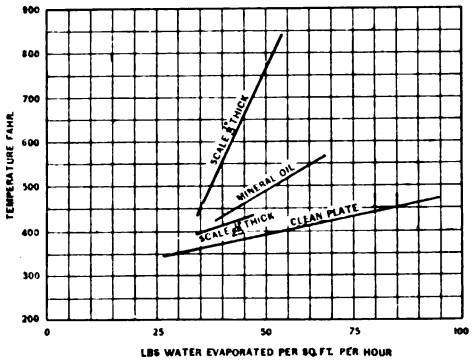

FIG. 2.
Temperature on Fire Side of Boiler Plate $\frac{3}{8}$ inch thick when Evaporating Pure Water at 212° F. Water Side of Plates clean, and coated with Scale and Oil. (Hirsch.)

parison between temperatures on the fire-side (1) when using a clean plate, and (2) with a layer of scale one-fifth inch thick, shows the former to be about 380° F., and the latter 665° F.—an increase of 285° F. It might be mentioned that iron at 750° F. is just visible in the dark as a dull red. Table I., which is made up of extracts from Sir A. Durston's experiments on the effect of grease in boilers, again shows the great retardation of heat transmission, and the heating of boiler plates from this cause (Proceedings of the Institution of Naval Architects, 1893).

Figs. 3 and 4 show graphically the fall of temperature from the flame to the fire-side of the plate, and thence to the water-side, for two of the experiments in Table I. The fall from one side to the other (or thermal head) with a clean plate was 28° F., while a coating of grease 1/32 inch thick increased this to 118° F.—*i.e.*, 90° F. more than when using a clean plate. These two experiments were carried out with water boiling at atmospheric pressure. Had the pressure been, say, 200 lbs. per square inch (steam temperature 388° F.), and assuming the thermal heads to remain as before, then the temperature at the fireside would have been 416° F. with the

* Paper read before the Institution of Electrical Engineers, Dublin Local Section, April 13, 1905.

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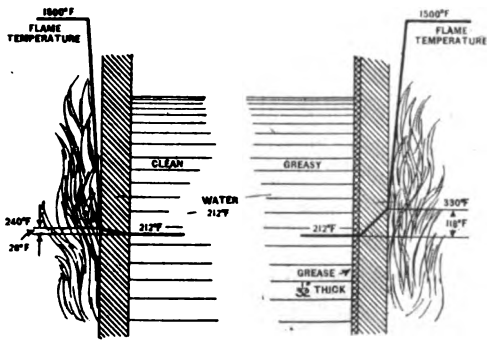
TABLE I.—SHOWING TEMPERATURES OF PLATES WITH CLEAN AND GREASY SURFACES (DURSTON).

Experiment.	Thickness of plate.	Thickness of grease.	Temperature of fire.	Temperature fireside of plate.	Temperature of water.	Difference.
	In.	In.	F°.	F°.	F°.	F°.
A	¼	—	1,500	240	212	28·0
B	¼	—	2,200	280	212	68·0
C	⅜	—	over forge full blast	430	344·5	85·5
D	¼	1/32	1,500	330	212	118·0
E	⅜	1/16	over forge full blast	510	359	151·0
F	¼	1/16	2,500	above 550	212	above 338·0
G	⅜	1/16 spread up sides	over forge full blast	617*	80	537·0

REMARKS.—Experiments A, B, D, and F were made with open vessel and water boiling at atmospheric pressure. C, E, and G were made in a closed vessel and under pressures corresponding to temperatures given.

* This temperature was reached three minutes after placing vessel on fire.



FIGS. 3 AND 4.
Diagram showing Fall of Temperature from Flame to Water with Clean and Greasy Plate.
(*See* Durston's Experiments, A and D, Table I.)
Greasy Plate 90° F. hotter than Clean Plate.

clean plate and 506° F. with the greasy plate. All these experiments show how rapidly the temperature of boiler plates increases as scale or oil is deposited on their surface. Eventually, when the deposit is sufficiently thick, collapse ensues, with possible loss of life. Even if the plate temperatures are barely high enough to bring about such serious results, they are quite sufficient to set up enormous varying strains each time the fire-door is opened, ultimately causing grooving and other defects to appear.

The "remedy" generally applied is to have the scale chipped off, entailing considerable expense, and putting the boiler out of work for a time. "Prevention" is preferable, and can be accomplished by "softening" and "purification" in proper treatment apparatus before the feed water enters the boiler. The boiler should not be used for any other purpose than raising steam. All patent compositions for treatment of the water inside the boiler should be carefully avoided. If used, they form soluble matter and precipitates inside the boiler, and they are too often added to the water with utter disregard to the proportions necessary for proper precipitation. These compositions generally contain some of the reagents used in water-softening apparatus, and often, in addition, substances injurious to boilers. I have heard of an analysis of one such preparation showing the presence of metallic mercury.

Softening.—Water is a powerful solvent, and whether taken for domestic or technical purposes from reservoirs, wells, rivers, lakes, etc., it has invariably, before being collected, come in contact with some part of the earth's surface, and in so doing dissolved or carried away certain substances, the amount of which may vary from practically nil to considerable quantities. Rain-water, if collected in the country, may be nearly pure, whilst in some districts mineral waters are found, the salts in which are present to such an extent as to impart to them a distinct taste or smell. The salts found in waters which chiefly concern engineers are given in Table II. These have been divided into scale-forming and non-scale-forming. Calcium and magnesium, in combination with other elements, are freely distributed in nature. The carbonates and sulphates of calcium and magnesium are the chief cause of "hardness" in water.

The hardness of water is judged by its

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TABLE II.—PRINCIPAL "SCALE-FORMING" AND "NON-SCALE-FORMING" SUBSTANCES.

Scale-forming.		Non-scale-forming.	
Substance.	Symbol.	Substance.	Symbol.
Calcium carbonate . .	$CaCO_3$	Calcium nitrate . . .	$Ca(NO_3)_2$
Calcium sulphate . .	$CaSO_4$	Magnesium sulphate .	$MgSO_4$
Magnesium carbonate .	$MgCO_3$	Magnesium nitrate . .	$Mg(NO_3)_2$
Magnesium hydrate . .	$Mg(OH)_2$	Magnesium chloride .	$MgCl_2$
		Sodium chloride . .	$NaCl$
		Sodium sulphate . .	Na_2SO_4
		Sodium nitrate . . .	$NaNO_3$

behaviour with soap in giving effect to the phenomenon called "lathering." Hard water, when used with soap, forms a lather with difficulty; soft water, on the contrary, readily does so. With hard water a considerable amount of soap is used before the lather is formed, and it may be observed that a scum appears on the surface. This scum is formed by the action of the soap in neutralising the salts causing hardness, or, in other words, part of the soap is used or destroyed in softening the water. As previously stated, the salts which chiefly cause hardness are those of calcium and magnesium, and the reaction between soap and one of these may be represented by the typical equation :—

$$\underset{\text{Soap or sodium stearate.}}{2NaC_{18}H_{35}O_2} + \underset{\text{Calcium sulphate.}}{CaSO_4} = \underset{\text{Sodium sulphate.}}{Na_2SO_4} + \underset{\text{Calcium stearate (Insol. Curdy ppt.)}}{Ca(C_{18}H_{35}O_2)_2}$$

The acid radicle of the soap combines with the calcium to form calcium stearate, a curdy precipitate, which is the scum referred to. Sodium sulphate is also formed, but as this compound does not destroy soap, no hardness is caused by its presence. When hard water is used for washing purposes, as has been stated, considerably more soap is required than when soft water is used, just under 1¾lb. of soap being required per 1° hardness per 1,000 gallons. Thus, for instance, even when using Dublin Vartry water, which is soft, over 6 lb. of soap would be required to soften 1,000 gallons of it before a lather could be formed. Other waters are sometimes used in Dublin, and I have a sample of water from a well in the city which would destroy about 250 lb. of soap per 1,000 gallons before being softened.

Many years ago Dr. Clark took advantage of the fact that waters of different hardness require different quantities of soap to form a lather, and he applied this in his method of estimating the hardness of water. He made a standard soap solution of such strength that the number of cubic centimeters of it required to produce a lather, when shaken with a given volume of sample water, indicated the degree of hardness of that water. In this country a degree is considered as one grain of calcium carbonate, or its equivalent in other soap-destroying salts, in one gallon of water. In many other countries the hardness is expressed as parts of calcium carbonate in 100,000 parts of water.

Table III. gives the most common soap-destroying salts found in water, also their equivalent values relatively to calcium carbonate—*e.g.*, a water containing 1·36 grains of calcium sulphate per gallon would be equivalent to 1·00 grain of calcium carbonate, or 1° hardness. The hardness of water may generally be reduced by prolonged boiling. The hardness which is removed in this way is called "temporary" hardness, and that remaining "permanent" hardness, the "total" hardness being the sum of the two.

Temporary Hardness.—Temporary hardness is caused by the presence of carbonates of calcium and magnesium, held in solution in the water as bicarbonates by the presence of carbonic acid. By boiling water containing bicarbonate of calcium or magnesium the carbonic acid is driven off, and the insoluble carbonate is precipitated thus :—

$$\underset{\text{Soluble.}}{Ca(HCO_3)_2} = \underset{\text{Insoluble.}}{CaCO_3} + H_2O + CO_2$$

Where only temporary hardness exists, the water may, therefore, be treated by heating, but the process is costly unless exhaust steam can be used, in which case oil is sometimes introduced into the boiler. About 1½ cwt. of coal would be required to heat up 1,000 gallons of cold feed to 212° F., and as prolonged boiling is afterwards necessary for

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TABLE III.—PRINCIPAL CALCIUM AND MAGNESIUM SALTS FOUND IN WATERS.

Salt.	Symbol.	‡ Combining weights.
Calcium carbonate* .	$CaCO_3$	100
Calcium sulphate† . .	$CaSO_4$	136
Calcium chloride . .	$CaCl_2$	111
Calcium nitrate . .	$Ca(NO_3)_2$	164
Magnesium carbonate*	$MgCO_3$	84
Magnesium sulphate .	$MgSO_4$	120
Magnesium chloride .	$MgCl_2$	95
Magnesium nitrate . .	$Mg(NO_3)_2$	148

* Held in solution as bicarbonate by presence of CO_2.
† For solubilities see Fig. 5. All these salts decompose soap.
‡ The combining weights are in this case equal to the molecular weights.

complete removal of temporary hardness, it is evident that boiling would not be economical as compared with chemical treatment. With exhaust steam treatment the heating is generally insufficiently prolonged to properly precipitate the carbonates. In some systems, by a combination of heating and introduction of sodium carbonate, both the temporary and permanent hardness are treated.

Table IV. shows approximately the limits of temperature between which certain salts are precipitated, by heating the water in which they are dissolved. The carbonates of calcium may also be decomposed by soap, as shown in a previous formula.

TABLE IV.—APPROXIMATE TEMPERATURES AT WHICH SALTS DISSOLVED IN WATER WILL BE PRECIPITATED.

Salt.	Symbol.	Precipitating temp. F°.
Calcium carbonate . .	$CaCO_3$	180–260
Calcium sulphate . . .	$CaSO_4$	100–430
Magnesium chloride . .	$MgCl_2$	212–270
Sodium chloride . . .	NaCl	330–380

The most successful and economic method of treating temporary hardness is by Dr. Clark's process. Nearly all patent appliances of the present day treat the carbonates of calcium and magnesium in this way. The principle of the process lies in the fact that by adding "lime water" (calcium hydrate) to waters containing calcium or magnesium carbonates held in solution by carbonic acid, the lime water combines with the carbonic acid to form calcium carbonate:—

$$\underset{\text{Bicarbonate of calcium. Soluble.}}{Ca(HCO_3)_2} + \underset{\text{Lime water. Soluble.}}{Ca(OH)_2} = \underset{\text{Calcium carbonate. Insoluble.}}{2CaCO_3} + 2H_2O$$

The reaction for magnesium carbonate is somewhat different, and may be shown thus:—

$$\underset{\text{Magnesium bicarbonate. Soluble.}}{Mg(HCO_3)_2} + \underset{\text{Lime water. Soluble.}}{Ca(OH)_2}$$

$$= \underset{\text{Magnesium carbonate. Slightly soluble.}}{MgCO_3} + \underset{\text{Calcium carbonate. Insoluble.}}{CaCO_3} + 2H_2O$$

The magnesium carbonate produced is only slightly soluble. If, however, twice the quantity of lime water shown in the above equation be added instead, then the second chemical equivalent of lime water acts thus upon the magnesium carbonate produced above:—

$$\underset{\text{Slightly soluble.}}{MgCO_3} + \underset{\text{Soluble.}}{Ca(OH)_2} = \underset{\text{Insoluble.}}{CaCO_3} + \underset{\text{Magnesium hydrate. Insoluble.}}{Mg(OH)_2}$$

Magnesium hydrate is produced, and forms as a gelatinous substance which is likely to choke the filters. It is thus not always advisable to add the excess of lime water necessary for converting the magnesium carbonate.

Permanent hardness.—The chief cause of permanent hardness is due to sulphates of calcium and magnesium. Calcium sulphate is soluble in water at ordinary temperatures. Fig. 5 shows that its solubility increases up to about 100°F., and then, contrary to the general rule, decreases at higher temperatures, until at ordinary boiler pressure temperatures it is considerably reduced—*e.g.*, of the calcium sulphate in solution at 100°F., only about

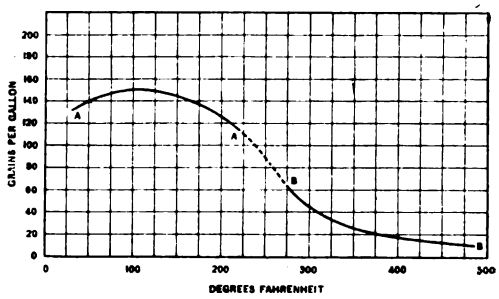

FIG. 5.
Solubility of Calcium Sulphate in Water at Different Temperatures.

Curve AA, *from experiments by Marignac.*
Curve BB, *from experiments by Tilden and Shenstone.*

17 per cent. would remain in solution at a temperature corresponding to a pressure of 150 lbs. per square inch, the remaining 83 per cent. having been precipitated to form incrustation in the boiler. The heaviest

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deposits obviously occur over the hottest part of the furnace. When such a boiler is cooled down, the calcium sulphate scale will be partly dissolved, and will concentrate in crevices of the scale. On heating up, it will again be deposited in these, and cement the whole more firmly than before. This is further accentuated if calcium carbonate is present in the scale.

Magnesium sulphate (better known as Epsom salts) is, as indicated in Table I., a non-scale-forming salt, very soluble, and causes permanent hardness. If this salt is concentrated in a boiler in contact with calcium carbonate scale, the following reaction may take place under certain conditions of temperature :—

$$\underset{\text{Calcium carbonate.}}{CaCO_3} + \underset{\text{Magnesium sulphate.}}{MgSO_4} + H_2O = \underset{\text{Calcium sulphate.}}{CaSO_4} + \underset{\text{Magnesium hydrate.}}{Mg(OH)_2} + CO_2$$

The magnesium hydrate formed unites with the calcium sulphate to form a vitreous scale, so that although magnesium sulphate is a non-scale-forming salt, it should not be allowed to concentrate in a boiler on this account.

If water containing calcium sulphate be treated with sodium carbonate, the following reaction takes place :—

$$\underset{\text{Soluble.}}{CaSO_4} + \underset{\text{Soluble.}}{Na_2CO_3} = \underset{\text{Soluble.}}{Na_2SO_4} + \underset{\text{Insoluble.}}{CaCO_3}$$

The insoluble calcium carbonate is precipitated and settles down. The sodium carbonate formed remains in solution, and as it does not decompose soap, the water is softened. To prevent concentration of the sodium sulphate or other salts, it is essential that boilers be periodically "blown off." This need not be done more frequently than is usual with properly worked boilers using untreated water.

Magnesium sulphate may be precipitated by treating with lime water, the reaction which takes place being as follows :—

$$\underset{\text{Soluble.}}{MgSO_4} + \underset{\text{Soluble.}}{Ca(OH)_2} = \underset{\text{Insoluble ppt.}}{Mg(OH)_2} + \underset{\text{Partly soluble.}}{CaSO_4}$$

Calcium sulphate is undesirable, and therefore the magnesium sulphate should preferably be treated with sodium carbonate :—

$$\underset{\text{Soluble.}}{MgSO_4} + \underset{\text{Soluble.}}{Na_2CO_3} = \underset{\text{Slightly soluble.}}{MgCO_3} + \underset{\text{Soluble.}}{Na_2SO_4}$$

Magnesium sulphate may also be precipitated by the addition of sodium hydrate (caustic soda) with this reaction :—

$$\underset{\text{Soluble.}}{MgSO_4} + \underset{\text{Soluble.}}{2NaOH} = \underset{\text{Insoluble.}}{Mg(OH)_2} + \underset{\text{Soluble.}}{Na_2SO_4}$$

If, however, lime water and sodium carbonate are added to each other, sodium hydrate is produced :—

$$\underset{\text{Insoluble.}}{Na_2CO_3} + \underset{\text{Soluble.}}{Ca(OH)_2} = \underset{\text{Insoluble.}}{CaCO_3} + \underset{\text{Soluble.}}{2NaOH}$$

As both sodium carbonate and lime water are used in treating other salts, their presence may be taken advantage of for the precipitation of the magnesium sulphate—thus :—

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 = CaCO_3 + Mg(OH)_2 + Na_2SO_4.$$

Chlorides and nitrates of calcium are likewise acted upon by sodium carbonate alone, or by sodium carbonate plus calcium hydrate.

It will be observed that the salts in water which are the chief cause of temporary and permanent hardness are removed by two reagents only—*viz.*, lime water and sodium carbonate. The lime may be added in the form of lime water, which is the clear liquid obtained by dissolving lime (CaO) in water, or by "slaking" quicklime with excess of water. Fig. 6 shows that lime is not very soluble in water, even at its maximum solubility. It can, however, be added to less water than is required to entirely dissolve it, and if the whole be kept stirred or agitated a milky fluid known as "milk of lime" is obtained, which may be used in softening water. Both lime and carbonate of soda are

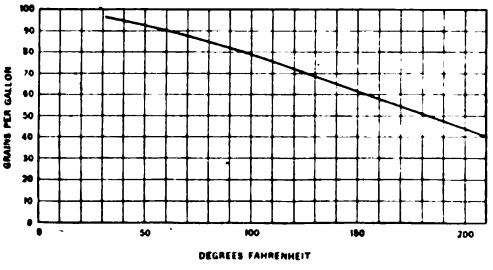

FIG. 6.
Solubility of Lime in Water at Different Temperatures. (Lanny.)

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TABLE V.—SHOWING CHIEF SALTS CAUSING TEMPORARY AND PERMANENT HARDNESS AND TREATMENT FOR REMOVAL.

Hardness.	Cause.	Treatment.	Reaction.
Temporary	Calcium bicarbonate $Ca(HCO_3)_2$	(1) Boiling	$Ca(HCO_3)_2 = CaCO_3 + H_2O + CO_2$* (Soluble. Insol. ppt.)
		(2) Adding lime water	$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$ (Soluble. Sol. Insol. ppt.)
	Magnesium bicarbonate $Mg(HCO_3)_2$	(1) Boiling	$Mg(HCO_3)_2 = MgCO_3 + H_2O + CO_2$ (Soluble. Slightly sol.)
		(2) Adding lime water	$Mg(HCO_3)_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + 2H_2O$ (Soluble. Soluble. Slightly sol. Insol.)
		(3) Adding further lime water	$Mg(HCO_3)_2 + 2Ca(OH)_2 = 2CaCO_3 + Mg(OH)_2 + 2H_2O$ (Soluble. sol. Insol. Insol.)
Permanent	Calcium sulphate $CaSO_4$†	Adding sodium carbonate	$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3$ (Sol. Sol. Sol. Insol.)
	Magnesium sulphate $MgSO_4$§	Adding sodium carbonate	$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4$‡ (Sol. Sol. Slightly sol. Sol.)
	Magnesium chloride $MgCl_2$§	Adding sodium carbonate	$MgCl_2 + Na_2CO_3 = MgCO_3 + 2NaCl$ (Sol. Sol. Slightly sol. Sol.)
	Magnesium nitrate $Mg(NO_3)_2$§	Adding sodium carbonate	$Mg(NO_3)_2 + Na_2CO_3 = MgCO_3 + 2NaNO_3$ (Sol. Sol. Slightly sol. Sol.)

REMARKS.—* $CaCO_3$ if precipitated slowly, as in economisers, forms a hard scale; if the precipitation is rapid, as in boilers, the deposit is in the form of mud. † $CaSO_4$ forms no scale in economisers, but a hard scale in boilers (see Fig. 5). ‡ Na_2SO_4 does not decompose soap. § These three salts are liable to cause corrosion; if it is desired to convert the slightly soluble $MgCO_3$ to the insoluble $Mg(OH)_2$, lime water may be added with the sodium carbonate, the typical reaction then being :—

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3 + Na_2SO_4$$
(Sol. Sol. Sol. Insol. Insol. Sol.)

inexpensive and easily obtained. The latter is used in the form of "soda ash."

Table V. shows a summary of the chief causes of temporary and permanent hardness and means of removing these. It will be observed that the last three magnesium salts are acted on by sodium carbonate, producing the partly soluble magnesium carbonate. Caustic soda, if used as a reagent, produces the insoluble magnesium hydrate. The latter reagent, as previously stated, is formed by the combination of lime water and sodium carbonate.

The quantities of reagents required to treat water can be found from the molecular weights of the hardening salts (see Table III.), and the reactions given in Table V. Thus 0·56 grains of lime are required to precipitate one grain of calcium carbonate, or, in other words, 0·56 grains of lime are required for each 1° of temporary hardness per gallon, or 0·08 lb. for each 1° per 1,000 gallons. With lime at 20*s.* per ton, the cost would be 0·00856*d.* per 1° per 1,000 gallons. In the same way 0·152 lb. sodium carbonate would be required for each 1° of permanent hardness, and this at £4 per ton would amount to 0·0649*d.* per 1° per 1,000 gallons. Each degree of permanent, therefore, costs over 7½ times as much to remove as each degree of temporary hardness, or 1,000 gallons with 58° temporary hardness costs for lime ½*d.*, and 1,000 gallons with 7·7° permanent hardness costs for soda ½*d.*

Most water softeners consist of the following: (1) tanks or vessels for containing the chemicals or reagents: (2) apparatus for distributing the chemicals in their proper proportions; (3) tank or vessel in which the hard water is treated; (4) filters for retaining the precipitates formed. The distributing apparatus should be automatic in regulating the supply of reagents according to any variation which may occur in the quantity of

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hard water requiring treatment, and should also be capable of being readily adjusted if the hardness of the water should vary. The filters should also be designed for rapid and efficient cleansing, with minimum delay in the working of the plant, should renewals of filtering medium (which generally consists of either wood, wool, sponge, cloth, or sand) be required. Some filters are made in sections, each of which can be by-passed when cleaning, thus enabling the filters to be cleaned without interrupting the work.

Below are the results of tests I have made on the hardness of three Dublin waters :—

	Hardness, Degrees Clark.		
	Vartry.	Canal.	Well.
Temporary hardness .	0·55	10·0	20·0
Permanent hardness .	3·35	5·0	130·0
Total hardness. . .	3·90	15·0	150·0

Purification.—The injurious effects of oil introduced into a boiler have already been pointed out. If the condensation water from the condenser of an engine be collected in a glass vessel and examined, it will be found to have a milky appearance, due to the presence of minute globules of emulsified oil in suspension. These globules, if allowed to enter the boiler with the feed water, to a large extent adhere to the plates. How a thin film of oil on a boiler plate should hinder heat transmission to such an extent as to become dangerous, is a subject which has been the cause of much discussion. To obviate risk, the condensed steam may be run to waste, and fresh feed water used. Assuming this is done in a station with an average output of 500 kw., the steam consumption being equal to about 1000 gallons of water per hour at 6*d.* per 1000 gallons, equals 12*s.* per day, or over £200 per annum. This only represents about one-half the saving, as, before a comparison can be made, the cost of heating up the cold feed to the temperature of the condensed steam (say 100°F. to 130°F.) would have to be taken account of. As the cost of working a purifier is very small, a total saving is effected worth serious consideration.

Oil in the exhaust steam on the way to the condenser cannot be completely arrested, neither can it be separated from the condensation water by mechanical filtration. The globules of emulsified oil are of such minute dimensions that they will pass through filter paper as easily as through the finest-woven fabric. Fig. 7 shows diagrammatically a comparative ratio between the size of a mesh of fine fabric and that of a particle of emulsified oil.

The most successful method of satisfactorily eliminating oil in this condition is by chemical means. Chemicals are introduced into the condensation water; this brings about a reaction which envelops the oil particles with a precipitate, causing them to adhere together in sufficiently large groups to render

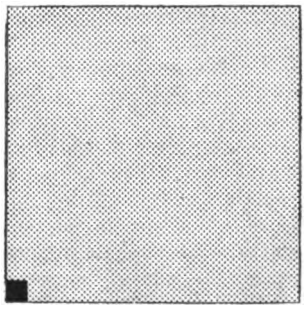

FIG. 7.

Approximate Ratio of Area of Mesh of Fine-Woven Fabric to average size of Globule of Emulsified Oil in Condensation Water.

Area of mesh 300 *times as great as area of globule.*

filtration easy, the resulting filtrate being perfectly clear. The reagent generally used is aluminium hydrate ($Al_2(OH)_6$), readily prepared by the interaction of sodium carbonate on aluminium sulphate :—

$$Al_2(SO_4)_3 + 3Na_2CO_3 + 3H_2O = Al_2(OH)_6 + 3Na_2SO_4 + 3CO_2.$$

The sodium carbonate and aluminium sulphate are added to the condensation water, and form the aluminium hydrate precipitate which surrounds the oil particles.

Another method of purification recently tried is by electrolysis, whereby the emulsified condensation water is used as an electrolyte. Electrodes are introduced into this, the current acting upon and precipitating the oil in such a form that it can afterwards be filtered.

The essential parts of chemical purifiers are similar to those already mentioned for softeners.

It would scarcely be possible in this paper to describe the numerous water softeners and purifiers on the market, but anyone desirous of investigating the working of the former will find valuable information in a recent paper on the subject by Messrs. Stromeyer and Baron (Proceedings, Institution of Mechanical Engineers, 1903, p. 773).

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ARMOURED CONCRETE.

PART III.

By Lieut. HENRY J. JONES, A.O.D., A.R.C.Sc. (Lond.), Inspector of Ordnance Machinery.

THREE distinct methods are adopted for the erection of work in armoured concrete. Some contractors build the whole of the work in suitable pieces, in sheds adjacent to the site, or at a central workshop from which they are sent to the place required when ready for erection. In this way large quantities of columns, piles, beams, floor slabs, etc., are kept in stock, and are available for immediate dispatch. Others erect an elaborate timber falsework *in situ*, on which the green concrete is tipped and rammed into close contact with the armouring, which is laid according to the design as the work proceeds. This plan makes first-class carpentry a necessity, and also requires a costly system of shoring to keep the falsework up to its intended position when the concrete is laid and rammed. A third method is to erect the armouring first, and then to build the concrete round it, suitable moulds being used, partly supported by the existing armouring. The system adopted will depend to a great extent on the nature and architectural elaboration of the finished work. For warehouses and factories, where many similar columns, piles, floor slabs, beams, etc., are required, the first system has an obvious advantage from an economical point of view; whereas for bridge work, the second, or a combination of the second and third systems, is the only one possible. In the construction of tunnels, pipes and sewers, the system adopted will depend upon the magnitude of the work, and the conditions under which it will have to be carried out: as a rule the third system would be adopted.

FLOORS, SLABS AND ROOFS.

The system of construction for floors, slabs, and roofs is determined by the extent of the work and the nature of the loads to be carried. If intended for small buildings and offices, the items can be made before erection; but in the case of warehouses, factories, piers, and jetties, where live loads and vibratory stresses have to be borne, a monolithic structure should be secured by building in moulds directly on the site. For the lighter classes of monolithic structure, expanded metal is admirably suitable; it is also much used for the roofs of reservoirs, and for thin partition walls. The meshing is simply laid over the ribs or floor beams, which have been already erected, and the green concrete is applied to the required thickness, being supported from below by suitable supporting work, which is removed as soon as the concrete has set. In cold storage factories, the floor beams and ceilings are invariably erected first, the floor being laid afterwards. The ceiling is then solid with the floor beams on their under side, and the floor is solid with them on their upper side, the air space between being a great aid to the maintenance of a low temperature for refrigeration.

When laying floors, care should be taken to prevent the upper layers of green concrete setting too quickly, particularly if the climatic conditions are such as to favour a rapid drying of the surface of the concrete. If precautions are not taken, unsightly cracks will result, which will afterwards have to be filled with cement. A good plan is to damp the surface of the concrete every three or four hours, for three days after concreting, and to cover the surface with canvas covers or tarpaulins. Floors are finished when necessary by setting bevelled sleepers in the soft concrete, and then nailing the floor boards to the sleepers. The sleepers are spaced at about two feet centres. Factories and warehouses usually have their floors finished by a layer of cement mortar, using one of cement to two of sand. This finish should be applied while the concrete is fresh and soft; but when this is not possible, the concrete should be scraped, guttered, and washed with water before the mortar is spread. Granite chippings small enough to pass a $\frac{3}{8}$-inch gauge are often added to the mortar to form the finish for the corridors of public buildings. For reservoir floors and walls, the concrete is guttered by horizontal grooves about $\frac{1}{2}$-inch deep and $\frac{3}{8}$-inch wide, the gutters being spaced at about 6-inch centres; the concrete has then two layers of asphalt applied to it, each layer being about $\frac{3}{8}$-inch thick, the grooves preventing the asphalt creeping or slipping over the concrete.

Roofs are made practically in the same manner as floors, but are usually much lighter.

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Floors should never be reduced below 4 inches in thickness, to avoid cracking; on the other hand, roofs are often only 2 inches in thickness if the armouring is of the expanded metal type, or expansion arising from changes of temperature is provided for by placing the armouring in both directions—in length and breadth. Roofs can advantageously be covered with a 1-inch layer of asphalt to ensure water-tightness.

In the Monier floors the armouring consists of round rods varying from $\frac{1}{4}$ inch to $\frac{5}{8}$ inch diameter. The rods are spaced at about six times their diameter, and are crossed at right angles, being connected by iron wire bound round them. This artificial method of securing the rods takes considerable time, and is thus a somewhat costly process. To produce continuity of metal, the different lengths of rods are overlapped for about 8 to 16 inches, and bound with wire. The weight w of a floor in lbs. per foot super, when built on this or the Hennebique system, may be taken to be given by the relation

$$w = 12t + 15,$$

where t is the thickness of the floor in inches.

Table I. gives particulars of slabs constructed on the Monier system, designed to carry $1\frac{1}{2}$ cwts. per foot super above the dead load of the floor itself. The armouring is spaced at about 3-inch centres.

When floors are continuous over the supporting walls or columns, tensile stresses are set up on the upper side, and armouring has to be suitably placed to take these tensile stresses. The safe load for floors on the Hennebique system is proportional to the square of the thickness of the floor, the percentage of armouring being invariably over 2 or 3 per cent. Table II. gives the live loads in lbs. per foot super. which Hennebique floors can carry for different spans.

The thickness of the floor may, however, be advantageously increased, and the percentage of armouring decreased, from the values given in the above table.

The Schlüter are similar to the Monier floors, but the rods are crossed diagonally, and the longitudinal rods are of the same size as the transverse ones. The Cottancin floors have their rods interlaced like the canes of a chair seat or a basket, and the Hyatt floors have square rods with holes through which small transverse rods pass. Over fifty systems of armouring are in use, and in most cases the only points of difference are the shape of the section and the method of attachment and adjustment. The floors may be calculated from the formula—

$$72\,bt^2 = M;$$

t being the thickness of the floor in inches, b the span in feet, and M the maximum bending moment in lb.-feet. The floors calculated by the above formula have $2\frac{1}{2}$ per

TABLE I.—PARTICULARS OF SLABS CONSTRUCTED ON MONIER SYSTEM.

Span in feet.	Depth in inches.	Diameter of longitudinal rods in inches.	Diameter of transverse rods in inches.
3	2·0	$\frac{9}{32}$	$\frac{1}{8}$
4	2·5	$\frac{5}{16}$	$\frac{1}{8}$
5	3·0	$\frac{11}{32}$	$\frac{3}{16}$
6	4·0	$\frac{13}{32}$	$\frac{3}{16}$
7	4·5	$\frac{7}{16}$	$\frac{3}{16}$
8	5·0	$\frac{7}{16}$	$\frac{1}{4}$
9	6·0	$\frac{1}{2}$	$\frac{1}{4}$
10	6·5	$\frac{1}{2}$	$\frac{1}{4}$
11	7·0	$\frac{9}{16}$	$\frac{1}{4}$
12	7·5	$\frac{19}{32}$	$\frac{5}{16}$
13	8·5	$\frac{5}{8}$	$\frac{5}{16}$
14	10·0	$\frac{5}{8}$	$\frac{5}{16}$
15	11·0	$\frac{5}{8}$	$\frac{5}{16}$
16	12·0	$\frac{5}{8}$	$\frac{5}{16}$

TABLE II.—LIVE LOADS, IN LBS. PER FOOT SUPER. FOR HENNEBIQUE FLOORS OF DIFFERENT SPANS.

Thickness of floor in inches.	Span in feet.											
	5	6	7	8	9	10	11	12	13	14	15	16
3·0	450	300	200	140								
3·5	600	400	280	200	140							
4·0		560	390	280	200	160	120	90				
4·5		690	500	370	270	210	160	130	100	70		
5·0			640	470	360	270	200	150	120	100	80	60
5·5			670	500	390	290	230	190	150	130	100	80
6·0				690	530	410	260	210	170	160	130	100

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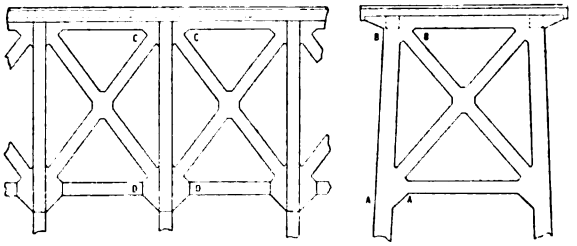

Side Elevation. *End Elevation.*

FIG. 1.—DESIGN FOR PIER, IN ARMOURED CONCRETE.

cent. of armouring, and are supposed to be merely resting on supports at the two sides of the span. If the floor is supported on four sides, the thickness will be $0{\cdot}7\,t$ calculated from the above formula; and if the floor is continuous over the four supports, the thickness will be $0{\cdot}6\,t$.

BEAMS.

It is obvious that, as the span increases, a limit will soon be reached beyond which it is not economical to use plain floor slabs, for their dead weight becomes of such magnitude as to prohibit their use. We have thus to resort to a division of the main span by cross

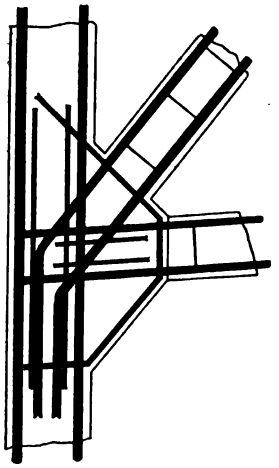

FIG. 2.—DISPOSITION OF ARMOURING AT AA, FIG. 1.

beams resting on columns, and the floor is laid on these beams, which are arranged to take as much of the load as to render it possible to reduce the thickness of the floor within reasonable limits. Armoured concrete beams are typical of the type of construction in which the merits of two component materials are made to serve a common end; but in the particular case of steel and concrete, the actual part played by the steel is not at all well understood. With columns and foundations in armoured concrete the work is either so stiff or massive that the tensile stresses induced by lateral or eccentric loading in the one case, or by uneven settlement in the other, are of very small magnitude compared with the compressive stresses induced by the dead load; thus the tensile stresses are amply met by the armouring, or it may be, are greatly met by the concrete itself. On the other hand, with beams, floors, arches, and pipes under internal pressure, the tensile stresses may be of such a magnitude as to work both the steel and the concrete to their safe limits, and thus it is to these examples of construction we must turn to get a just illustration of the practice and theory of armoured concrete. The need for any sort of reinforcement exists, owing to the liability of the concrete to fail under tensile stress. When, however, the tensile stresses are almost negligible, it is obvious that the use of the armouring will be somewhat obscure. We select the beam as being the most familiar example for illustration.

Speaking generally, beams do not differ in constructional details from floors. The same armouring is used in both, the only difference being, that as beams are usually deeper than floors, the shearing stresses become more pronounced, and greater pro-

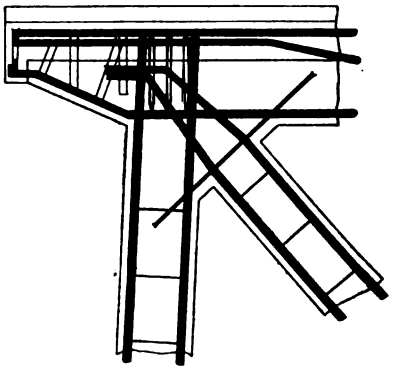

FIG. 3.—DISPOSITION OF ARMOURING AT BB, FIG. 1.

vision has to be made for them by a liberal use of stirrups or vertical binding rods. In some systems the armouring consists entirely of straight rods, disposed in any part of the beam where tensile stresses are likely to be called into play. In others, specially bent rods are joined or welded to straight rods, and when welding has to be done it would appear that wrought iron is more suitable than steel. Fig. 1 shows the side and end elevation of a pier in armoured concrete; the disposition of the armouring in the beams,

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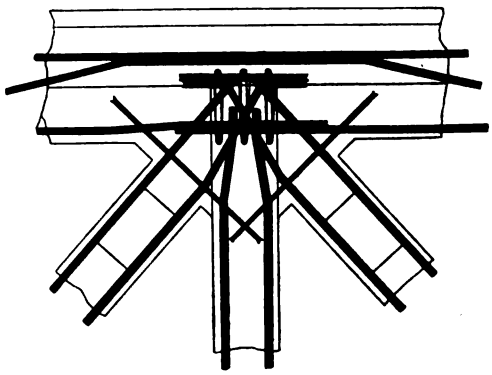

FIG. 4.—DISPOSITION OF ARMOURING AT CC, FIG. 1.

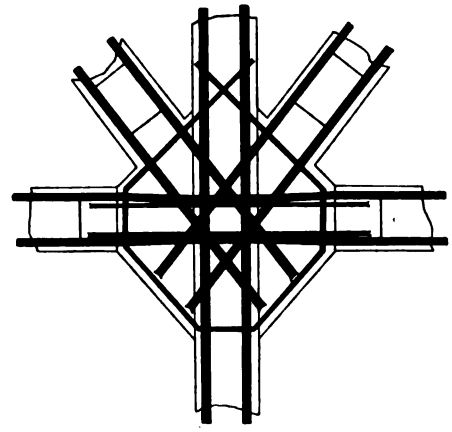

FIG. 5.—DISPOSITION OF ARMOURING AT DD, FIG. 1.

piles and cross-beams, is shown in Figs. 2, 3, 4 and 5. Fig. 2 illustrates how beams are connected and secured to the piles, and the use of straight and bent rods in the armouring. Figs. 3 and 4 show how the stirrups are employed where the shearing stresses are most intense. The beams and piles gave, on the average, about 3 per cent. of armouring, the diameter of the rods varying from 1 inch down to $\frac{3}{8}$-inch diameter, the stirrups being made to suit the depth of the beams. Four rods were used in each beam and pile, but in some very heavy work as many as twenty-four rods have been used.

It is usual to arrange the dimensions of the beams so that the whole of the compressive stresses are taken by that portion of the concrete on one side of the neutral axis; but in some cases, as with continuous beams or heavy beams of small depth, a proportion of the armouring is distributed along the compressed portion of the beam, the steel rods either taking up the excess of compressive stress over that at which the concrete can be safely worked, or else taking up the tensile stresses at the places where they occur over the supports. As a general rule we may take it that the economical depth for an armoured concrete beam, freely supported at both ends, is one-twentieth the span, and is thus approximately the same as that of a steel girder of equal strength. Armoured concrete beams are now made for spans up to 100 feet for buildings, and 150 feet for bridges. But for each class of work beyond this limit, the weight becomes excessive. Several arched ribs for much greater spans have, however, been successfully built.

The beams are made in much the same way as piles and columns: they can be made in sheds on the site, or in the actual position they are to occupy when finished. The green concrete is tipped into moulds made of a 2-inch bottom plate, carrying by clamps or screws, and two 2-inch side plates. When being made in their final position, the moulds are shored from below every five feet, and the shoring is not removed until at least three or four weeks after the concrete has been laid. As before stated, the ceiling and beams are erected first, the floor being afterwards worked on the top of the beams. We thus obtain a very perfect monolithic structure in which any vibration set up by machinery, falling loads, etc., will be of much less extent than with an ordinary type of building, in which there is often a great want of rigidity, the beams and arches being loosely connected and able to vibrate independently of other parts of the structure.

Experiments have shown that whereas ordinary concrete columns will crack when a load is carried which causes an extension per unit length of $\frac{1}{10.000}$, columns armoured with a suitable percentage of steel are able to give ten times this extension without showing any signs of fracture. The explanation of this important fact is to be found in this, that unarmoured concrete is heterogeneous in structure, and any extension which takes place will be almost wholly confined to weak sections which are certain to exist, however much care be taken in the mixing and ramming of the materials. Thus, since the strength of concrete in tension is determined by the tensile strength of the matrix, which is low, we must expect fracture to occur at a comparatively low stress. The effect of the armouring would appear to consist in rendering possible a more even distribution of the stress over the weak sections, in giving a more uniform extension to the column, and

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in taking up the whole of the tension at points where the matrix has been worked beyond its yield point. This fact is particularly interesting in the case of beams. Simple concrete beams invariably fail on the tensile side, by diagonal cracks arising from the combined action of the tensile and shearing stresses; and this failure occurs long before the compressed portions of the beam have been worked to their safe limit, the maximum deflection being very small. With concrete beams having a suitable percentage of properly disposed armouring, quite new elastic properties are realised, and the beam can be loaded to give ten times its former deflection without visible sign of fracture by cracking on the tensile side. The permanent set with armoured beams is also much less than that with plain beams. The reason of this increased range of elastic properties will become clear when considering the theory of armoured concrete beams.

(To be continued.)

THE DETERMINATION OF MANGANESE IN STEEL AND PIG IRON.

By FRED IBBOTSON, B.Sc.

THE determination of manganese in steel can be made in a number of ways. Of the gravimetric methods, the precipitation as hydrated peroxide, after removal of the iron, is very accurate when carefully conducted; the volumetric methods consist in the conversion to permanganic acid, without removal of the iron, and titration with a suitable reducing agent.

Gravimetric Method.—Four grams of the drillings are placed in a conical flask of 30 oz. capacity, and covered with 40 cc. of concentrated hydrochloric acid. When, on heating, the steel has nearly all dissolved, a few cc. of strong nitric acid are added to oxidise the ferrous chloride, and the solution is diluted with lukewarm water to about 500 cc. The excess of free acid is then neutralised by adding dilute ammonium hydrate whilst the flask is being shaken vigorously. This neutralisation is complete when the liquid begins to darken in colour, although to litmus it yields an acid reaction; the darkening in colour is due to the production of basic chloride of iron formed by the ferric hydrate at first precipitated dissolving in the ferric chloride. It is then advisable to continue the so-called neutralisation by substituting ammonium carbonate solution for the hydrate. Each addition of the carbonated alkali produces a brown precipitate which, on vigorous agitation, dissolves with effervescence and the formation of a darker-coloured solution. The darkening in colour continues after each addition, until the solution in bulk appears to be almost black. At this stage the basic ferric chloride contains about seven-eighths of the iron in the form of hydrate, but there is still no precipitate. On adding more ammonium carbonate, a copious brown precipitate forms which will no longer dissolve on shaking. Hydrochloric acid is then cautiously added until the precipitate just dissolves with the production of the black solution again. It is desirable that as little acid as possible be used for this purpose, and in consequence the flask is shaken vigorously after the addition of each few drops before adding more.

The liquid is now diluted nearly to a litre with hot water and placed over a Bunsen. The basic ferric chloride begins to decompose with precipitation of ferric hydrate before boiling point is reached, and when this happens, or at any time subsequently, about 10 cc. of ammonium acetate solution, made by neutralising strong ammonium hydrate (0·880) with B.P. acetic acid, are added. The contents of the flask are maintained at boiling point for three minutes to effect complete precipitation of the iron, and then transferred to a litre flask. Hot water is then added until the total volume is about 5 cc. more than the litre. This allowance is made for the volume of the precipitate, although the results are not sensibly influenced by ignoring it altogether. After

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taking the temperature of the mixture, 500 cc. are filtered off through a large dry folded filter paper; or, better still, the whole mixture is poured from the litre flask into the conical flask in which the precipitation was made, and the latter, after covering with a watch glass, is allowed to stand in a warm place for about five minutes; after this it will be found possible to pour 500 cc. of the clear supernatant liquid through a dry filter paper without seriously disturbing the precipitate. The clear and colourless filtrate in the half-litre flask is then heated to the temperature previously noted, superfluous liquid being removed by means of the thermometer. This bulk of liquid represents, therefore, two grams of the steel; the remaining liquid and precipitate are thrown away.

As thus conducted, the separation of manganese from ferric iron occupies less than half-an-hour, and is complete. There may be a trace only of iron in the filtrate, but the precipitate is absolutely free from manganese, and the operation of redissolving and reprecipitating, as often recommended, is altogether unnecessary.

The filtrate is cooled rapidly, about 10 cc. of bromine added so that, on shaking, the solution is saturated and a small quantity left undissolved, and strong ammonium hydrate is added to alkalinity. The manganese is thus precipitated as hydrated peroxide; this, on digestion with occasional shaking, rapidly "flocks out," and it may then be filtered through an ashless paper. After washing and drying, the paper and precipitate are ignited together at a bright red heat in a platinum crucible; the final residue is Mn_3O_4.

$$Mn_3O_4 \times 0{\cdot}72 = \text{manganese.}$$

The trace of ferric oxide in the ignited residue, which ought not to exceed one milligram, is determined by dissolving in hydrochloric acid, evaporating to low bulk, and adding ammonium thiocyanate. The red colour thus obtained is matched by means of a standard solution of ferric chloride treated similarly and diluted to the same volume.

Volumetric Method.—1·1 grams of the drillings are dissolved in a boiling tube in 30 cc. of nitric acid (s.g. 1·20). After expulsion of the nitrous fumes by boiling, sodium bismuthate is added in small quantities at a time, to oxidise the carbonaceous matter, with boiling between each addition. The oxidation is complete when, as generally happens with most steels, a brown precipitate of manganic oxide persists after boiling. This precipitate is cleared by the addition of a few drops of sulphurous acid or of ferrous sulphate solution, and the liquid is then cooled under the water tap. To the nearly colourless solution thus obtained about 2 grams of sodium bismuthate are added, and the mixture is shaken for a minute or two. The tube is allowed to stand whilst a filter of ignited asbestos is being prepared, and the permanganate is then filtered off and washed with water containing a few drops of nitric acid. When the washings are colourless, the filtrate is treated with $\frac{N}{20}$ solution of ferrous ammonium sulphate, delivered from a burette, until the colour is more than completely discharged. The excess of ferrous iron thus added is determined by the careful addition from a burette of an exact $\frac{N}{20}$ potassium permanganate solution until a faint pink tint is reproduced. The number of cc. of ferrous solution added, less the excess, registers the manganese.

$$1 \text{ cc. of } \frac{N}{20} \text{ solution} = 0{\cdot}05 \text{ p.c. manganese.}$$

The ferrous ammonium sulphate solution, made by dissolving 19·6 grams of the crystals in a litre of water freely acidulated with sulphuric acid, must be frequently standardised against the permanganate. The latter is made by dissolving 1·58 grams of the pure crystals in a litre of pure water; the solution thus obtained is stored in dark blue bottles and kept in the dark, when its strength remains practically constant.

The residue on the asbestos filter dissolves freely in hydrochloric acid with generation of chlorine. After thorough washing with water, the asbestos can be used for a further determination.

Sodium bismuthate is an article of commerce, but it can be readily prepared by heating 20 parts of sodium hydrate nearly to redness in an iron crucible, and adding 10 parts of dried basic bismuth nitrate, a little at a time. Two parts of sodium peroxide are then added, and the fused mass is poured on to an iron plate. When cold, the brown mass is powdered, washed by decantation several times with hot water, collected, and dried.

In the case of grey irons, the graphite should be filtered off after dissolving in 1·20 nitric acid.

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SPECIAL DEVICES USED IN WEAVING.

PART VIII.—SOLID OR TUBULAR PIRN-COP WINDING MACHINES (*continued*).

[*All Rights Reserved.*]

By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

ANOTHER modification of a solid pirn-cop winding machine is illustrated by Figs. 48, 49, and 50.* In its general construction and the method of driving spindles, it bears a close resemblance to that of Grayson's described in the previous article. The chief points of difference between the two machines are in the means to effect the automatic stoppage of spindles, both when the supply of yarn to them fails, and also when cops attain to their full length. With a view to facilitating reference and comparison of the two machines, analogous parts in both are, as far as practicable, indicated by corresponding letters or figures.

Spindles I are disposed vertically at regular intervals apart, and are driven, as in Grayson's machine, by means of bevel wheel gearing. Each spindle is furnished with a jaw clutch E, that engages (on setting a spindle in motion) with a lug D cast upon a small bevel wheel C. This remains constantly in gear with a skew-geared driving wheel B, fixed upon driving shaft A, which extends along the full length of the machine, and contains the loose and fast driving pulleys, 16 and 17. The construction of bevel wheels C, and the means of supporting them, as well as the position which they occupy in relation to their respective driving wheels B, are commendable features of this machine worthy of special notice. It will be observed that bevel wheels C are each formed with a long boss or sleeve R, contained within a hole bored in cross-rail 18, which serves both as a support and bearing for the wheel. It will also be seen that wheel C gears with its driving wheel B *below*, and not above, the axis of driving shaft A. These circumstances

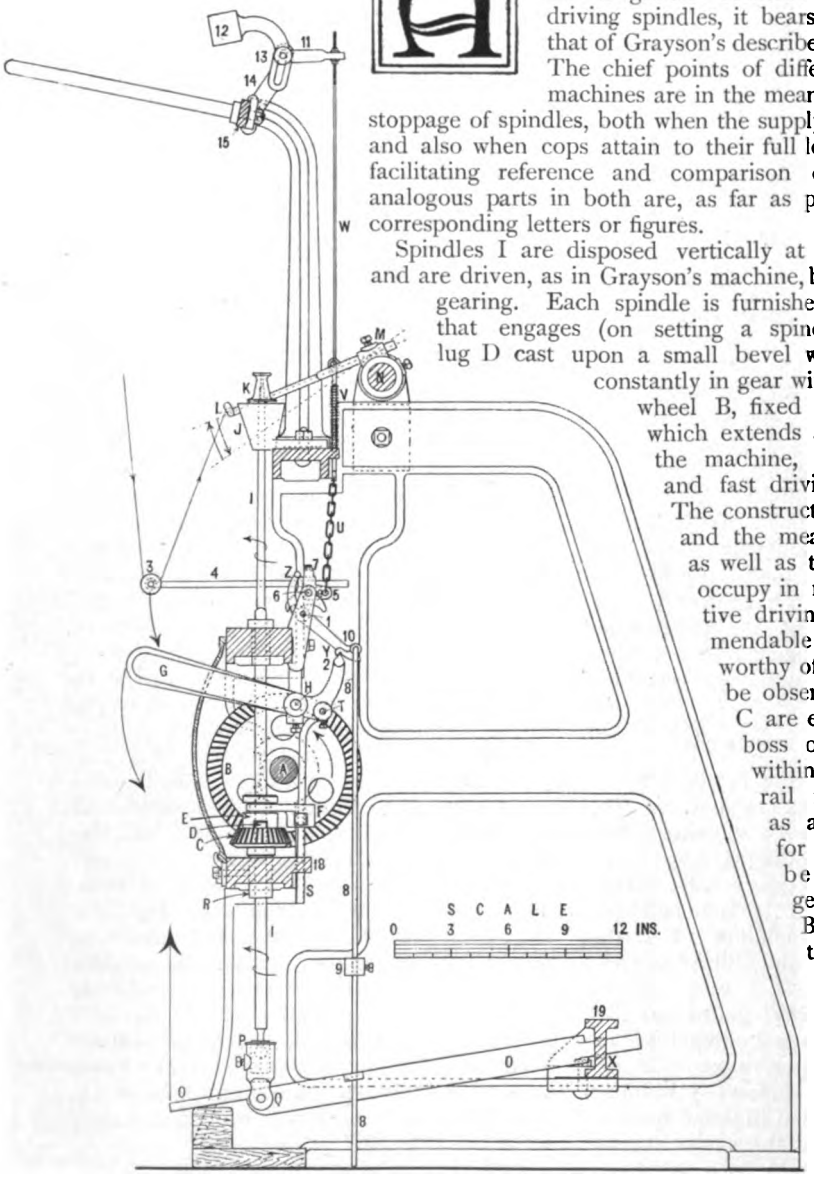

FIG. 48.—SECTIONAL ELEVATION OF SMITH'S UPRIGHT SOLID PIRN-COP WINDING MACHINE.

* For permission to use Figs. 48–50, and Figs. 52 and 53, the writer here acknowledges his obligation to the makers, Messrs. Wm. Smith and Brothers, Limited, Heywood, who have kindly supplied him with the original drawings of those diagrams.

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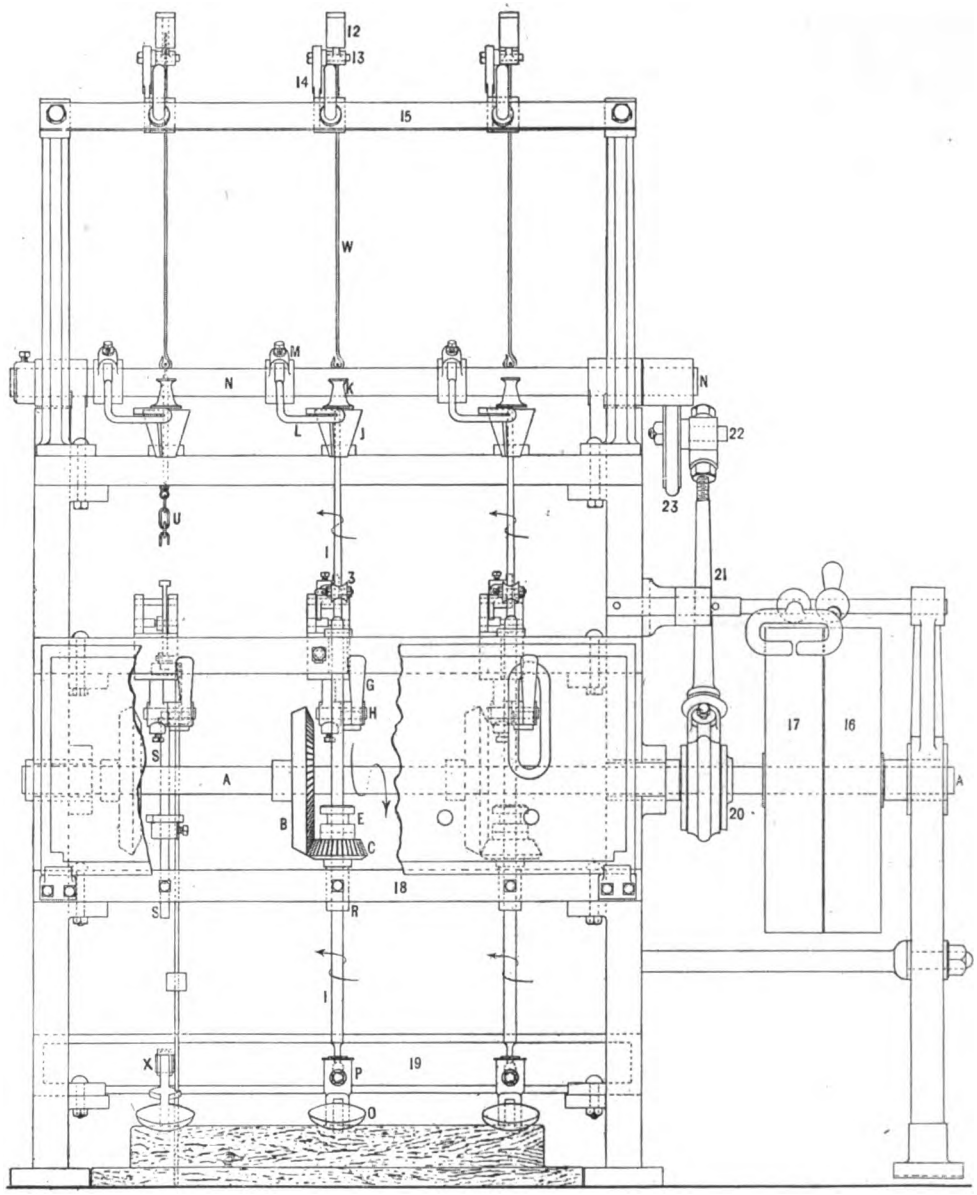

FIG. 49.—FRONT ELEVATION OF SMITH'S UPRIGHT SOLID PIRN-COP WINDING MACHINE.

combine to give firmer support to wheel C, which, when once properly adjusted, is prevented by gravitation from gearing too deeply with the teeth of wheel B. Hence, a steadier, smoother, and quieter action of the wheels is secured, and the tendency of teeth to become locked, and the consequent excessive wear and tear and breakage of teeth and wheels is reduced to a minimum. An advantage is also gained by placing spindles *forward* of the driving shaft, whereby they are brought nearer the front, and are, therefore, more accessible for operatives when piecing threads, removing fully-wound cops, and starting new ones. The lower extremity of a spindle is secured to a treadle lever O, through the medium of a ball-socket footstep P. The footstep is hinged upon a pin Q that passes through both the footstep and the treadle lever. The rear extremity of the latter freely enters a slot X, in rail 19, which serves as a free fulcrum for the lever,

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and permits of a slight lateral movement by it as its spindle ascends or descends in a strictly vertical plane, as indicated by an arrow.

A spindle is set in motion by engaging its clutch with the lug of its small bevel wheel (as represented in the diagrams), and will continue to revolve so long as they are kept in gear; but immediately the supply of a thread to its spindle fails, and also when a cop attains to its full length, the clutch is automatically raised beyond the control of the lug, thereby causing a spindle to stop. A clutch is put into and out of action in the following manner. The neck of a clutch is spanned by a fork F secured to a rod S that depends from the lighter and shorter end T of an unevenly-balanced lever G fulcrumed on a pin at H. The short end of lever G is extended upward, and pointed at the end to form a latch 2. Thus, by raising the forward end of lever G, its clutch is depressed until it engages with the lug of bevel wheel C, thereby setting a spindle in motion. At the same time, latch 2 is caught and retained by a catch or hook Y, fulcrumed pin 1, and extended upward with a curved arm terminating at Z. A clutch and lug will remain in gear until retaining hook Y is raised to release latch 2, and thereby cause lever G to disconnect them. Hook Y may be actuated from either of two independent sources, namely, by the descent of tension lever 4; and the ascent of treadle lever O; according to whether a thread fails in its supply to a spindle, and permits the tension lever to fall, or on a cop attaining to its full length, respectively. A tension lever 4 is secured to the vertical arm 7 of an L-lever (of which 5 is the horizontal arm), fulcrumed on a pin 6, and is supported, during winding, by means of a thread passing underneath a porcelain runner 3, contained on its forward extremity. If from any cause the tension lever falls (as indicated by an arrow), it causes arm 7 to bear against the upper arm Z of the hook Y, thereby raising the latter to liberate latch 2, and allowing the forward end of lever G to fall by gravitation (as indicated by an arrow), thereby raising the clutch out of gear with its bevel wheel, and causing its spindle to stop.

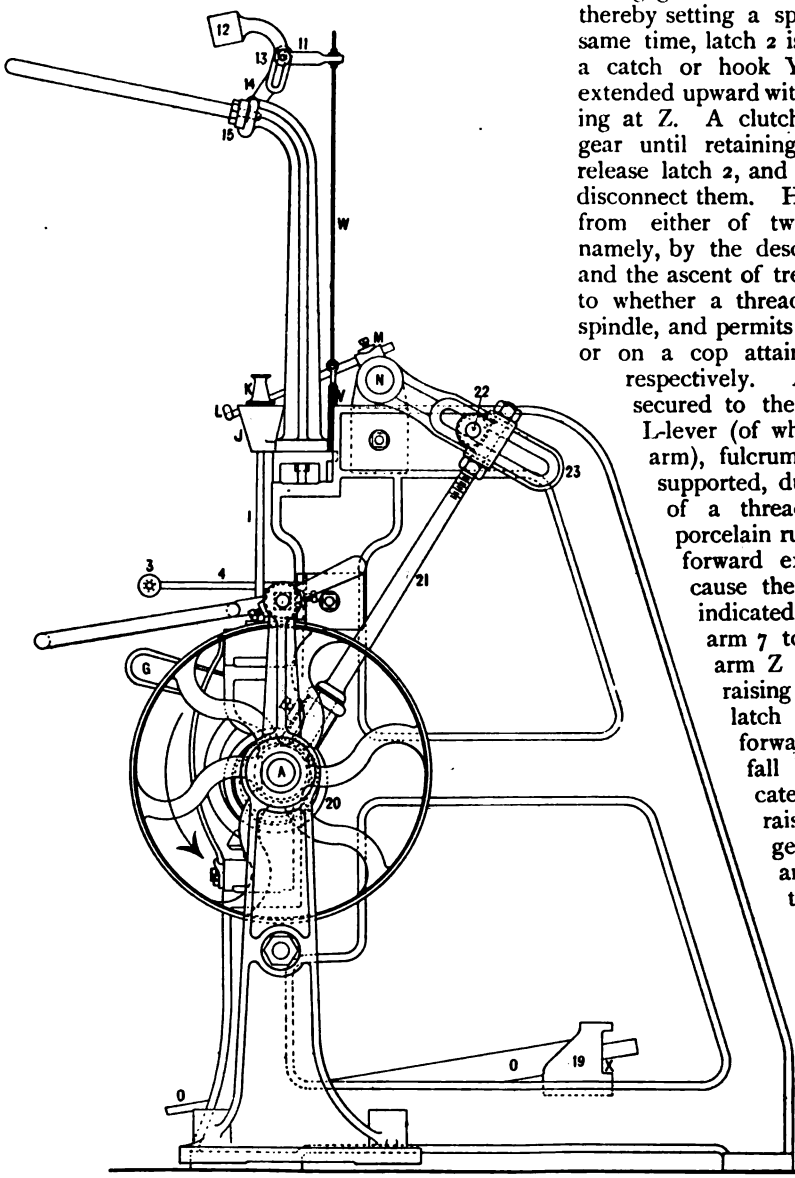

FIG. 50.—END ELEVATION OF SMITH'S UPRIGHT PIRN-COP WINDING MACHINE.

The liberation of a clutch from its bevel wheel, when a cop is completed, is effected as follows:—Depending from the rear extremity 10 of hook Y is a long slender rod 8 furnished with an adjustable hoop 9. The lower portion of rod 8

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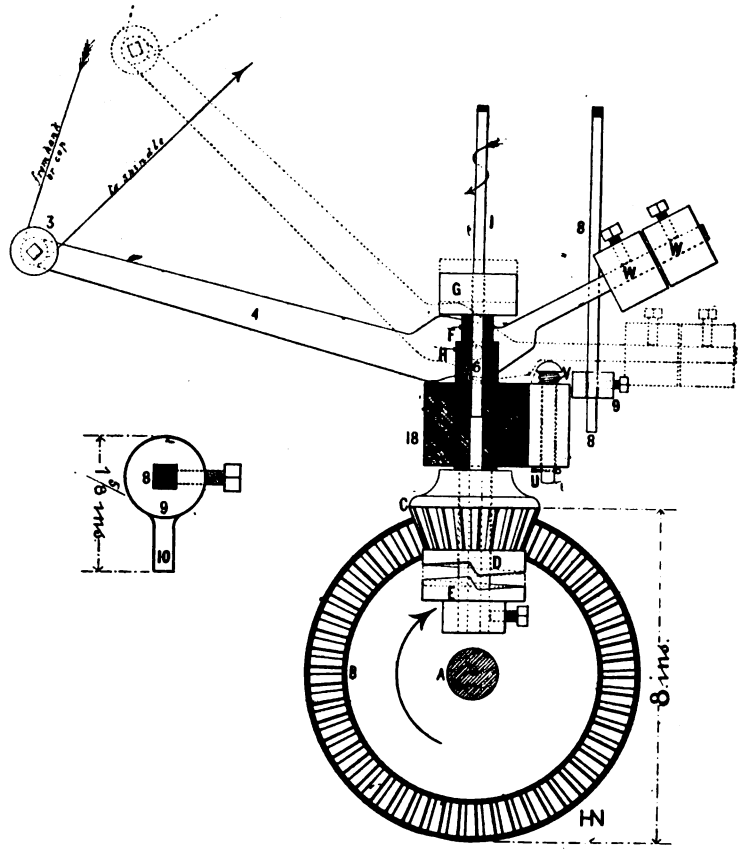

FIG. 51.—DETAILS OF AUTOMATIC STOP-MOTION, HALL'S SOLID PIRN-COP WINDING MACHINE.

passes through a hole formed in a side projection of treadle lever O. Hence, as a spindle rises, it raises its treadle lever, which eventually comes in contact with hoop 9, and lifts rod 8 until catch Y liberates lever G, whose short end rises and disconnects the clutch from the lug of its bevel wheel, thereby causing a spindle to stop.

A tension device is furnished to each spindle for the purpose of imparting tension to a thread, and also to maintain it at a uniform degree of tension during winding. This is accomplished by connecting arm 5, of L-lever 5, 7, by means of a link-chain U, a spring-rod and a wire-rod W, to the end of arm 11 of a weighted lever fulcrumed on a stud 13, that is fixed upon a bracket 14, supported upon rail 15. The free end of lever 11, which is weighted at 12, always tends to fall by gravitation, and thereby causes runner 3 to bear downward and keep its thread taut. The spring-rod passes through a hole in the cup-rail, and is encircled by an open spiral spring V, situated between the cup-rail and a stop-pin inserted in the spring-rod. The function of spring V is to provide a flexible connection that will yield in the event of a thread becoming slightly obstructed, from entanglement or otherwise, as it is withdrawn from its source. Thus, by gradually resisting the increasing tension of an obstructed thread, it tends to release it and thereby reduce breakages of yarn. The spring also serves to neutralise any irregularity in the withdrawal of a thread, by allowing the tension lever to oscillate and adapt itself to such variation, and thereby maintain it at an approximately uniform tension during winding.

The traverse of yarn is effected by means of an eccentric 20, fixed upon the driving shaft A. The eccentric communicates motion through the medium of rod 21 and connecting pin 22, to an arm 23 fastened to a shaft N, which extends along the full length of the machine, and carries brackets M, in which are fixed guiders L. The latter are caused to oscillate rapidly, and thereby impart a

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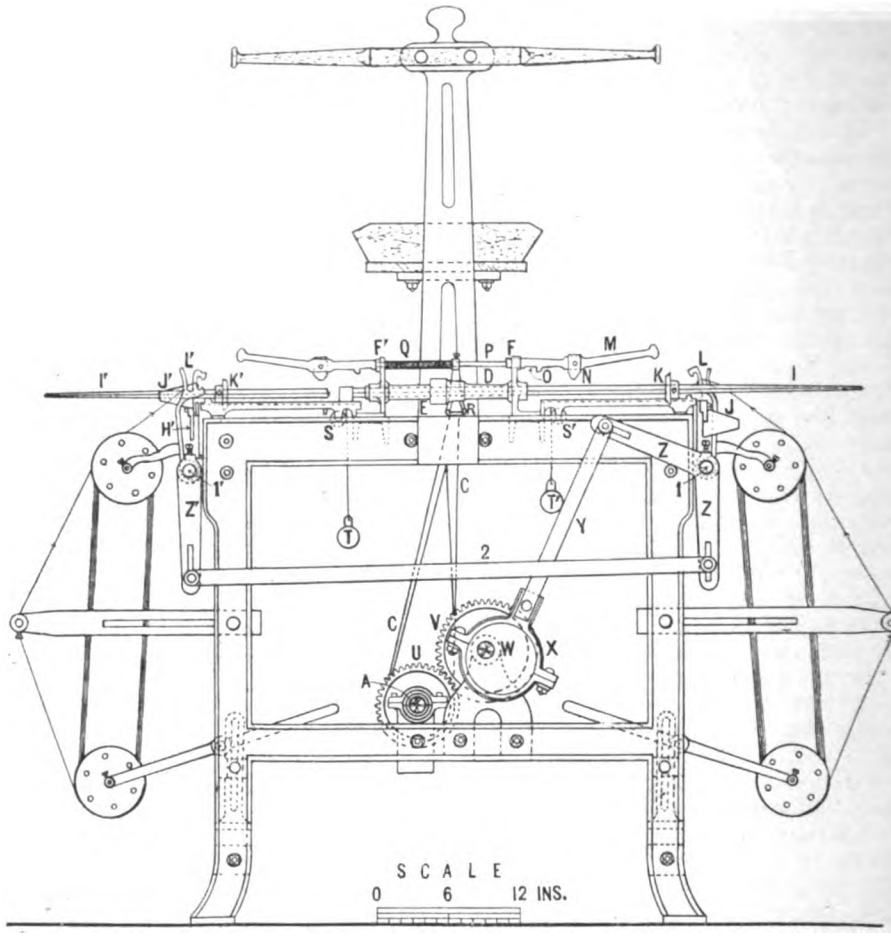

FIG. 52.—END ELEVATION OF SMITH'S HORIZONTAL SOLID PIRN-COP WINDING MACHINE.

quick traverse to the threads, so as to place them upon their respective spindles in successive layers of coarsely-pitched coils.

Fig. 51 is a part sectional diagram indicating the method of driving spindles, and also the means by which they are automatically put out of action, both when cops attain to their full size, and also when the supply of yarn to them fails in Hall's solid pirn-cop winding machine. As in the two previous machines of this type, spindles are rotated positively through the medium of small bevel wheels C, driven by, and always in gear with, large bevel wheels B, fixed upon driving shaft A. Each wheel C is formed with an upward tubular extension or sleeve H, whilst the base D forms a driving clutch, of which E is the driven counterpart that is set-screwed to the lower end of another and inner tube or sleeve F, surmounted by a driving collar or hoop G, which is fast upon the sleeve. A hole passes axially through both hoop G and sleeve F for the reception of a spindle 1. The hole through sleeve F is circular, but that through the hoop is exactly counter to the cross-section of a spindle, which is oblong, as represented in the diagram. Hence, a spindle may only be set in motion by causing hoop G to revolve. This is accomplished by raising the tension lever 4, which turns about pin 6 as a fulcrum; the result is that clutch E is raised, and engages with the driving clutch D. The tension lever is formed with a shoulder that bears against the under side of hoop G. Thus, by raising the tension lever to the position indicated by dotted lines, it raises hoop G, with its sleeve, until clutch E engages with driving clutch D, thereby setting a spindle in motion. When, however, the tension lever falls to the position indicated by full lines, hoop G and its sleeve are allowed to fall until clutch E is lowered sufficiently to place

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it beyond the control of its driving clutch, thereby causing a spindle to stop. A square rod 8, containing an adjustable hoop 9 with a projecting tongue 10 (shown enlarged in plan detached), depends from the head-piece of a winding spindle 1, so that the tongue 10 projects underneath a short arm forming the rear end of tension lever 4. Therefore, as a spindle gradually ascends during winding, it raises rod 8 with its hoop until the tongue of the latter lifts the rear end of the tension lever, thus causing the clutches to separate, and thereby cause the spindle to stop. This may be arranged to take place sooner or later, according to the position of hoop 9 on rod 8. By fixing the hoop higher or lower on the rod, it will act upon the tension lever sooner or later, and cause shorter or longer cops respectively to be produced. The rear arm of a tension lever is furnished with adjustable balance weights W, which may be adjusted so as to increase or diminish the pressure of the tension lever upon a thread, according to its counts and strength. Also, passing freely through holes in the rear of rail 18, are spring-pins U, supported by open spiral springs V, placed between the rail and pin heads. One of these pins is situated immediately under the short arm of each tension lever, to provide the latter with a buffer or cushion against which it abuts as it oscillates under the fluctuating tension of a thread, and thereby neutralise the effects of jerks and sudden straining caused by entanglement or other impediment to its regular withdrawal and delivery during winding. Such a device practically endows a tension lever with a certain degree of flexibility, whereby it is capable of yielding and adapting itself to the variable tension of a thread, and thereby reduce the risk of breakages of yarn to a minimum.

A solid pirn-cop winding machine of a distinctly different type of construction from any of those previously described under this head is represented in end and part front elevations by Figs. 52 and 53 respectively. In this machine, spindles 1, 1^1, are arranged horizontally, with consecutive spindles placed in opposite directions alternately, so as to form a row on each side, and thus constitute a duplex machine. They are rotated independently through the medium of long sleeves D, driven by means of narrow leather straps C, from flanged pulleys B fixed upon driving shaft A. Spindles are square in cross-section throughout their entire length, and are tapered at their forward end, on which cops are built, to facilitate their removal when completed. Each spindle passes freely through a sleeve D, borne by supports F, F^1, and formed with a square axial hole that is counter to the cross-section of a spindle. Hence, a sleeve D becomes the driving factor of a spindle, and permits of its gradual recession as it is forced backward by the resistance of a pirn-

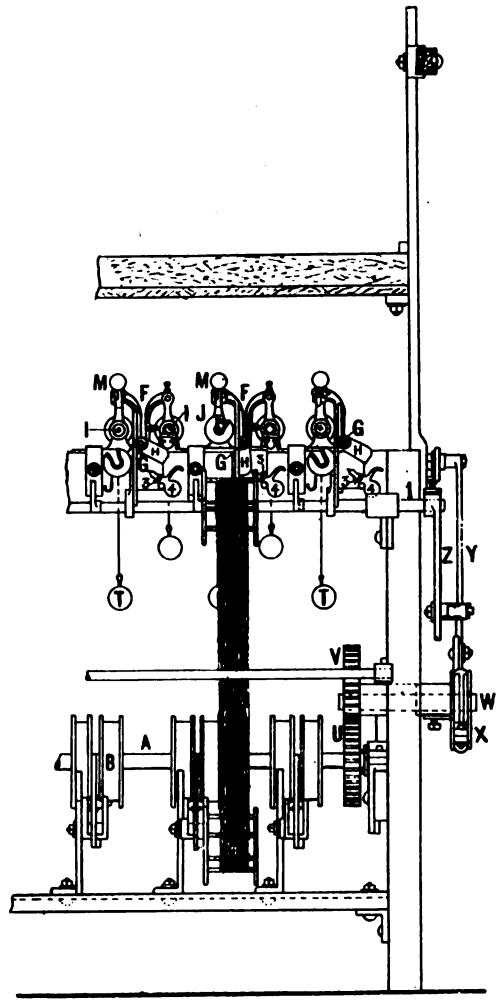

FIG. 53.—PART FRONT ELEVATION OF SMITH'S HORIZONTAL SOLID PIRN-COP WINDING MACHINE.

cup due to the constantly increasing length of a cop during winding. About midway between its supports a sleeve is formed with an enlarged circumference E to provide a driving surface for the reception of its driving strap. The latter is governed by a strap fork R, secured to rod P, extending from, and controlled by, a starting handle M. On

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pushing a handle backward, its strap is passed from the smaller circumference to the larger or driving circumference E of the sleeve, which along with its spindle, is thereby set in motion. When a starting handle is pushed backward, it becomes locked by means of support F taking into a notch O formed in the handle, and thus retains the driving strap on its driving surface; but if from any cause the handle is raised, it springs forward and moves the strap on to the smaller circumference (as indicated in the diagram), in which event it becomes slack and, therefore, incapable of gripping the sleeve, thereby causing a spindle to stop. This may be effected either by hand, and also automatically on a cop attaining to its pre-determined size; but not in the event of yarn either breaking or otherwise failing in its supply to a spindle. The automatic stoppage of a spindle is effected by causing an adjustable hoop or collar K, which is secured to the spindle, to eventually bear against an inclined edge of a projecting piece N on starting handle M, and thus raise notch O clear of its retaining catch, thereby causing a driving strap to become inoperative.

The machine under present notice also exhibits a departure from the usual practice of attaching pirn-cups J to the machine. These are not fixed by bolts, as is customary, but are hinged upon pins G, so that they may be temporarily swung aside from their spindles (as indicated in the diagrams) to permit of the removal of fully-wound cops. On returning a cup to its normal position, however, it becomes locked by the ascending end of a short unevenly-balanced lever 4, fulcrumed on a pin 3, bearing against a pendant arm H which is attached to the cup, as seen in Fig. 53. The yarn traverse motion, which presents no unusual feature, may be easily followed on the diagrams.

The use of leather straps for the purpose of driving spindles, and also the general simplicity of its construction, enables this machine to be worked with comparatively little noise and few breakages; which is in marked contrast to the deafening clatter of those machines in which spindles are driven positively by means of bevel wheel gearing and clutches. The disadvantage, however, of frictional driving by means of leather straps arises from their tendency to become slack, and thereby lose some of their driving power, with a consequently reduced speed of spindles and a loss of production. Also, the value of the machine from a practical standpoint would be greatly enhanced by the application of some means to cause spindles to stop automatically when the supply of yarn to them fails.

INDUSTRIAL CHEMISTRY.

Non-fusible Furnace Linings

In connection with our reference to the use of carborundum for furnace linings, which appeared in the May issue of Technics (p. 399), the following particulars for applying carborundum experimentally will doubtless be of interest. For use in furnaces, crucibles, cracked gas retorts, gas-producer chambers, forced draught grates, destructor furnaces and such-like fire-brick structures, it is only necessary to chip away glazed or fritted portions of the walls or linings, and then apply the following mixture:—

Water-glass (sodium silicate) of 42° Bé . . . 1 part by weight.
Carborundum powder . 3 parts by weight.

Mix carefully and intimately to ensure homogeneity. In the case of basic slags or linings it is best to add one part by weight of fireclay to every six parts of carborundum.

For all ordinary working temperatures a coating ½ m.m. thickness ($\frac{1}{50}$ inch) is ample, and only requires ⅓ to ¼ lb. of carborundum per square foot.

A New Disinfectant

Some interesting experiments have recently been completed, showing that Cyllin, the new disinfectant introduced by Jeyes' Sanitary Compounds Company, Limited, is thirty times as strong as carbolic acid as a germicide, and more than eighty times as strong as formalin. Most successful results have been obtained with time cultures in Agar of the *B. pestis*, in which the dilutions are very significant, that for 40% formalin being 1 in 30; pure phenol 1 in 80; and cyllin 1 in 2,400. With a dilution of 1 in 400, that virile organism of pus (*Staphylococcus p. aureus*) has been proved by a competent bacteriologist to be destroyed in five minutes. In many works it will therefore be of great value.

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SINGLE-PHASE ALTERNATING CURRENT RAILWAY WORK.

By LIONEL CALISCH, Assoc. City Guilds of London Institute.

IT is well known that electric railways and tramways are operated, by direct current, at a voltage of about 600. For heavy service, extended systems, and long-distance main line work, the cost of copper, sub-stations, etc., becomes enormous under these conditions. For the generation and transmission of electrical energy, alternating currents are principally used; transformers and rotary converters are required for changing the alternating into direct current.

Of course, a higher voltage than 600 direct could be employed, and the line losses and cost of copper reduced. Experiments on high-voltage direct current railway work have been carried out by Thury in Geneva; but practice has proved that about 600 volts is the best pressure for direct current working, and this is now taken as a universal standard.

Obviously, there would be a great advantage in a railway equipment which could be operated from an alternating current, high voltage supply without the use of rotary converters. For the last nine or ten years engineers have tried to solve this problem by means of the three-phase motor; at present a few three-phase railway systems are in use on the Continent, but, on the whole, three-phase motors are unsuitable for railway work (except in special cases such as mountain railways—for instance, the Jungfrau railway) for the following reasons:—

A three-phase motor is a constant-speed motor; that is, the speed remains practically constant with change of load. In a successful railway motor, on the other hand, the speed must vary with the load.

Another disadvantage in the three-phase system is, that it necessitates the use of two trolleys, and that the speed control is difficult and cumbersome.

As several articles have been written on this subject during the last few years, I need not dwell any longer on three-phase motors.*

Enormous progress has been made during the last two years with single-phase commutating motors; some lines in America are now being equipped with these, while one is already in commercial operation.

Single-phase motors may be classified as follows:—

1. Synchronous motors.
2. Induction motors.
3. Commutating motors.

Commutating motors may be divided into (*a*) series motors, (*b*) repulsion motors.

The first two types are entirely unsuitable for railway work, as the starting torque, efficiency, and power-factor are poor, while speed regulation is very difficult.

Reference, however, should be made to the Oerlikon Company's experiments; this company uses single-phase induction motors working at 15,000 volts from a trolley. The motor drives a direct current generator, which in turn supplies current to direct current motors. It is, however, unlikely that this system will be extensively used, as it is too costly and cumbersome.

It is to the last class of motors that we must look for the solution of the alternating current traction problem.

Commutating Single-Phase Motors.

Series Motors.—Since a direct current series motor runs the same way, whichever way its terminals are connected up, it is obvious that such a motor will run with an alternating current. Direct current series motors were used many years ago for alternating currents by simply laminating the pole pieces.

Owing to the high frequency of the currents supplied at that time (from 60 to 133 ∽ per sec.), bad results were obtained on account of heavy sparking at the brushes, so that it was found impossible to construct motors above 5 h.p.

Several of these small alternating current series motors were at that time in use on the Continent for driving small pumps, etc., and behaved very much like ordinary D.C.* series motors. After many years the series

* See Eborall, Institute of Electrical Engineers, vol. 33, page 316.

* D.C. stands for direct current, and A.C. for alternating current.

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motor has now once more come to the front; it has been greatly developed by Lamme and Steinmetz in America, and Finsi in Italy, and is now used for traction purposes.

A paper read by Steinmetz, before the American Institute of Electrical Engineers, * contains the results obtained by him and Mr. Eickenmeyer with alternating current series motors; from this it appears that an alternating current series motor suitable for railway purposes was being developed as early as the year 1891. Fairly good results seem to have been obtained, and it is surprising that the work was not continued.

The chief troubles connected with the earlier A.C. series motors were due to sparking, but by the use of lower frequencies now in use (25 ∽ per sec.) and the application of our present knowledge in regard to commutation and electrical design, machines have been built which do not spark excessively. Heavy currents are induced in the armature coils when they are short-circuited by the brushes, and these currents must be broken when the coils pass from under the brushes, and excessive sparking and demagnetisation of the field are produced. To reduce these currents somewhat, Lamme and Finsi use high resistance connections between the armature coils and commutator segments, which considerably improve commutation.

The power factor (a feature which does not need to be considered in direct current machines) is another important consideration. In the simple series motor (Fig. 1), the power factor is very low, because the armature and field windings in series with it offer a great impedance to the alternating current passing through them. The greater the current, the worse is the power factor; so that at starting the power factor is very low, but increases with the speed.

The efficiency of the A.C. series motor is not quite so high as in the D.C. series motor, on account of the iron and copper losses, which are considerable.

To overcome the difficulty of bad commutation and low power factor, Eickemeyer, as early as 1891, introduced the compensating coil, which lately has come to the front again. The object of the compensating coil is to counterbalance the self-induction of the armature. Compensation may be effected in two ways :—(1) the compensating coil may be in series with the armature and main current (Fig. 2); or, (2) the compensating coil may be short-circuited (Fig. 3), and acts as the short-circuited secondary of a transformer of which the armature is the primary. The current in the compensating coil is in opposition to that in the armature, and counterbalances the self-induction of the latter. The effect of this is to improve commutation and increase the power factor. It also slightly decreases the efficiency. Such a compensated motor has the true series characteristic, and can be operated equally well either on direct or alternating current supply.

The enormous advantage of the series motor is, that it can be operated either with A.C. or D.C. supply; thus it is possible to use the same motor on a line fed with D.C. and on another line fed with A.C.

In operating series motors on D.C. and A.C. supply, it is found that the best proportion for the field-windings for D.C. and A.C. running are different. The General Electric Company of Schenectady winds the field in two sections, which can either be thrown in parallel or in series (Fig. 4). For alternating current the sections are in parallel, because this gives a smaller self-induction; for D.C. running they are thrown in series. A properly designed compensated series motor, when running D.C., has almost perfect commutation; in fact, this is much better than in any ordinary railway motor, since the compensating coil balances the field distortion of the armature, and thus acts like the Ryan balancing coil.

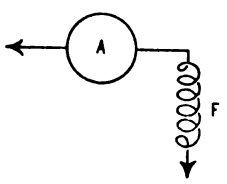

FIG. 1.
SIMPLE SERIES MOTOR.

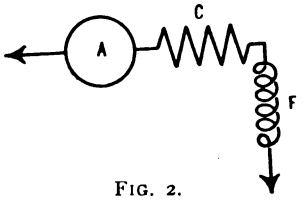

FIG. 2.
SERIES MOTOR, WITH SERIES COMPENSATING COIL.

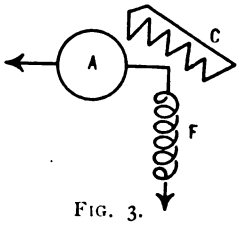

FIG. 3.
SERIES MOTOR, WITH SHORT-CIRCUITED COMPENSATING COIL.

A, *armature.* F, *field.* C, *compensating coil.*

* See *Electrician*, April 8th, 1904.

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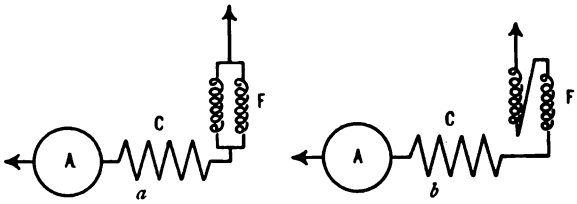

FIG. 4.—SERIES MOTOR WITH FIELD ARRANGED (*a*) FOR A.C., AND (*b*) FOR D.C.

Several articles have been written on the most suitable field construction. Osnos (*see Zeitschr. Electrotechn.*, Wien, 21, pp. 711–717, December 27, 1903, and *Science Abstracts*, vol. 7, No. 569, p. 219) has gone very fully into this question; he prefers the distributed winding, just as in an induction motor field, while Heubach, in his treatise *Der Wechselstrom-Serien motor*, arrives at the conclusion that the field winding should be as in continuous current motors, the poles being of course laminated. This question, however, does not seem settled. The Westinghouse Company uses laminated poles and field windings, as in an ordinary D.C. series motor, while the General Electric Company uses a winding distributed in slots, exactly like the stator of an induction motor.

Repulsion Motors. — Between the years 1884 and 1889 Professor Elihu Thomson carried out a series of important experiments on electromagnetic repulsions and rotations produced by alternating currents. One of the best known, and at the same time the most fundamental of his experiments, is that of throwing a closed metallic ring in the air by means of an electromagnet excited by an alternating current. A powerful electromagnet (Fig. 5) has a core consisting of a bundle of iron wires. As soon as the electromagnet is excited by means of a powerful alternating current, the copper ring shown in Fig. 5 is thrown up in the air, on account of the strong repulsive force exerted on it by the magnet. Under favourable conditions the ring may be thrown from twenty to thirty feet high.

These experiments led to the construction of Elihu Thomson's repulsion motor, which was shown at the Paris Exhibition in 1889. This motor (Fig. 6) consisted of a field having laminated pole pieces, and a direct current armature with its brushes short-circuited. On applying an alternating current to such a motor the armature revolves and yields mechanical power.

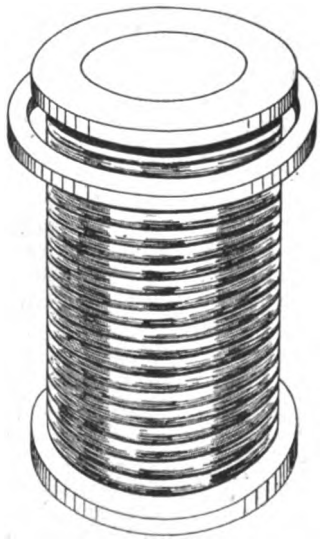

FIG. 5.—TO ILLUSTRATE ELIHU THOMSON'S EXPERIMENT ON ELECTRO-MAGNETIC REPULSION.

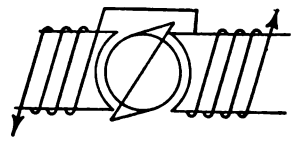

FIG. 6.—ELIHU THOMSON'S REPULSION MOTOR.

We can easily see that, at certain positions of the armature, an electro-magnetic repulsion will take place between the field and the short-circuited armature coil, and will thus set the armature in rotation. We may consider each armature coil, when short-circuited by the brushes, as the copper ring, which is thrown from the electro-magnet in Elihu Thomson's fundamental experiment.

It is worth while to go a little into detail, and to see how this repulsion is produced. Let us consider the simple copper ring experiment previously described. The magnetic field is an alternating one, and will vary periodically in strength; let us suppose it to follow the sine law. The ring, which forms a closed circuit, will have an E.M.F. induced in it, and this E.M.F. at any moment will

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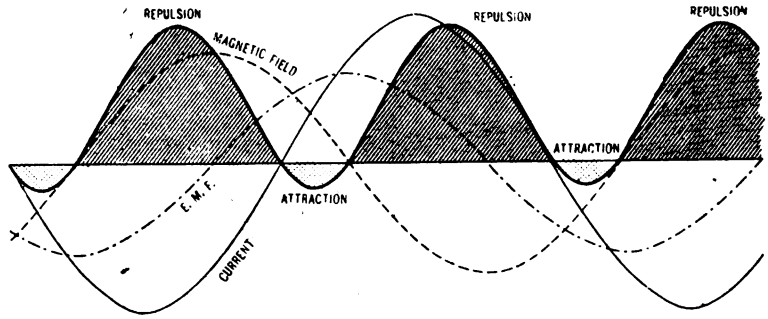

FIG. 7.—TO EXPLAIN THE PRODUCTION OF ELECTRO-MAGNETIC REPULSION.

be proportional to the *rate of change* of the magnetic flux (Fig. 7). This induced E.M.F. will give rise to an electric current which, however, will lag behind the induced E.M.F., since the ring possesses self-induction.

Now we know that the induced E.M.F. lags 90° behind the magnetic flux, and that the electric current in the ring lags behind the curve representing the induced E.M.F. in the circuit. We may, therefore, represent the magnetic flux, induced E.M.F., and induced current by the curves shown in Fig. 7. Now the force which acts on the ring at any moment is proportional to the product of the current flowing round the ring and magnetic field in which the ring is placed. If we multiply the numerical values of the ordinates (shown in Fig. 7) of the induced current and magnetic field curves, and set up new ordinates to represent these products, we obtain a new curve, representing the repulsive force to which the ring is subjected.

We see from the curve that the ring is alternately repelled and attracted; but the repulsions are much greater than the attractions, and therefore the ring is, on the whole, repelled. It can easily be seen that the repulsion curve depends almost entirely on the lag of the induced current, and therefore on the self-induction of the ring.

I have given this explanation of the ring experiment, because I consider it to illustrate the fundamental theory of the repulsion motor, and from this it can easily be seen how the repulsion motor acts and how the torque is produced.*

* For further information on electro-magnetic repulsions and attractions the reader may be referred to: Phil. Trans. Royal Soc., Vol. CLXXXIIIa., p. 279, "Repulsion and Rotation produced by A.C. Current," by Mr. G. T. Walker; Prof. J. A. Fleming, Proc. Royal Institution XIII., 296, March 6th, 1891, and Journal of the Society of Arts, May 14th, 1890, and his text-book "A.C. Transformer in Theory and Practice," pages 307–329; also Elihu Thomson, *Electric World* IV., 258, May 28th, 1887; XIV., 231, October 5th, 1889.

To return to the repulsion motor.

Elihu Thomson had no success with his motor on account of poor commutation; this was due to the high frequencies at that time in use. However, during the last few years it has come to the front again on account of the lower frequencies in use (25 ~ per sec.), and some excellent results have been obtained. The repulsion motor has an excellent starting torque, and behaves very much like an ordinary D.C. series machine. The modern repulsion motor consists of a laminated iron stator, having the windings distributed in slots (some prefer definite polar projections), just like an induction motor field.

The armature is almost the same as that of a direct current machine with its brushes short-circuited.

The repulsion motor has a very low power-factor at starting; its efficiency is not very high, and commutation is not very good. It is a "transformer" motor; there is no connection between field and armature, and it can therefore be wound for high voltages. Repulsion motors have been made up to 3,000 volts, as the armature can be designed in such a way as to commutate any current.

The simple repulsion motor can be modified in several ways. Repulsion motors may be classified as follows:—

1. Simple repulsion motor.

2. Compensated repulsion motor: (*a*) Compensated by having the coil in series with the field; (*b*) Compensated by having the coil short-circuited on itself; (*c*) Compensated by having the coil in series with the armature.

3. Inverted repulsion motor.

4. Inverted compensated repulsion motor: (*a*) Compensated by having the coil in series with the field; (*b*) Compensated by having the coil in series with the armature; (*c*) Compensated by having the coil short-circuited on itself.

5. Series-repulsion motors. (Winter-Eichberg.)

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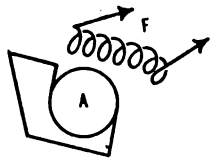
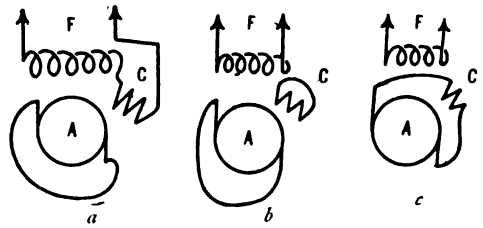
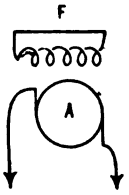


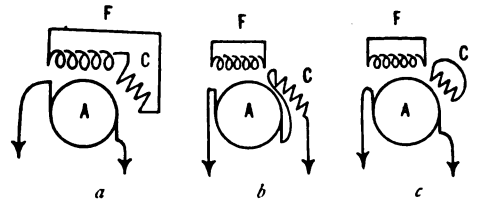
(1) *Simple Repulsion Motor.*



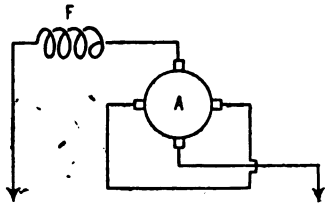
(2) *Compensated Repulsion Motor.*



(3) *Inverted Repulsion Motor.*



(4) *Compensated Inverted Repulsion Motor.*



(5) *Series Repulsion Motor.*

FIG. 8.—TYPES OF REPULSION MOTOR.

These motors, except the two first and the last, are of no practical importance; most of them are, however, very interesting from a theoretical standpoint, and perhaps some day they may come into practical use.

The inverted repulsion motor has its field short-circuited and the current is supplied to the armature. Fig. 8 will make the different types clear.

The last one (the series repulsion motor), has been devised by Winter-Eichberg, and is manufactured by the Union Electricitäts Gesellschaft. This firm seems to have obtained some excellent results with it. The great claim of this motor is that its power factor is nearly unity under all conditions of working, and that it is also able to work at high pressures. For a full account of this motor the reader may be referred to an article by F. Eichberg (*Electrotechn. Zeitschr.* 25, pp. 75-82).

Some excellent results have been obtained with the simple repulsion motor. W. I. Slichter, in a paper read before the Institute of Electrical Engineers in America (see *Electrical World and Engineer*, 43, pp. 266-267) gives the results which he obtained with two repulsion motors made by the General Electric Company. He carried out some experiments with two 60-h.p. repulsion motors, mounted on a 25-ton car. He came to the conclusion that the repulsion motor is very well adapted for rapid acceleration work, and for freight haulage at moderate speeds, and is more economical than a D.C. series machine.*

Comparison of the Series Motor with the Repulsion Motor.—The repulsion motor being a transformer motor, can be wound for high voltages; it has been built for 3000 to 4000 volts.

The series motor, on the other hand, is a low voltage motor (about 200 volts); it can run on either A.C. or D.C. supply, which is a decided advantage.

The repulsion motor can be run at a high voltage without the use of a transformer. On the other hand, it has a very low power factor at starting, causing a large wattless current, while the series motor has a better power factor at starting.

The starting torque of the repulsion motor is a little better than that of the series motor, but the running performance of the latter is much better than that of the former. The efficiency of the series motor is a little higher than that of the repulsion motor.

At present it seems that, on the whole, the series motor is the better. It is significant that both Finsi in Italy, and the Westinghouse and General Electric Companies in

* For information on repulsion motors, see C. P Steinmetz, *Electrical World and Engineer*, 43, pp. 268-271, 266-267; M. Latour, *Electrotechnische Zeitschrift*, 24, pp. 1027-1028; M. Osmos, *Electrotechnische Zeitschrift*, 25, pp. 1-6, 25-28; M. Latour, *Electrotechnische Zeitschrift*, 24, pp. 453-454.

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America, are developing the compensated series motor and use this for traction purposes.

The General Electric Company, who are the holders of Elihu Thomson's repulsion motor patents, abandoned this type of motor, after years of experimenting, in favour of the series motor.

Having considered the various single-phase motors which can be used for traction purposes, we come now to their application to railway work.

Control.—The speed can be controlled by varying the voltage at the motor terminals; this can be done by means of a transformer having several taps, or by means of an induction regulator. Further, we may use plain rheostat, or series parallel control, or we may have taps on the field. With voltage control, however, ideal conditions are obtained, as the waste of power at starting is done away with; the least power is therefore used at starting and at slow speeds. Here an enormous advantage over D.C. working is obtained. Another great advantage is that, with voltage control, we can make up for speed.

It is impossible, at present, to make up for lost time when a train is late. With A.C. working we can raise the voltage a little and, therefore, increase the speed.

A great number of estimates have been made comparing the cost of single-phase with that of D.C. working, using rotary converter sub-stations. In nearly all these cases the cost is less with single-phase working. Look at the enormous advantage of doing away with rotary converters and having high voltage trolleys. All we need are static transformers, which do not (like converters) require skilled attendance.

In urban and suburban work, where many stops are made, the saving of power with voltage control will be considerable. Both the Westinghouse and General Electric Companies are equipping roads with A.C. motors, and both companies have all sizes of A.C. series motors up to 200 h.p. on the market. A very successful car has been put in commercial operation between Schenectady and Ballston by the General Electric Company; this is equipped with compensated series motors, and runs both with A.C. and D.C. supply.

As I had something to do with this equipment, I will give a full description of it; this experiment proved to the whole world the success of the single-phase motor for traction work. From Ballston to Schenectady

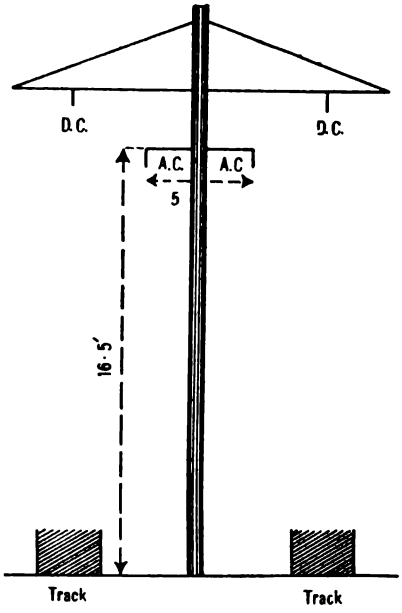

FIG. 9.
TO ILLUSTRATE COMBINED D.C. AND A.C. EQUIPMENT ON THE BALLSTON-SCHENECTADY LINE.

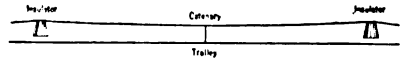

FIG. 10.—TO ILLUSTRATE METHOD OF SUPPORTING TROLLEY WIRE.

(State of New York) is 15·5 miles, of which 3·9 miles run through the city of Schenectady, which is equipped with 500 volts D.C. trolley.

The Ballston extension had for several months been operated with D.C. equipments, and their operation being continued, necessitated for the A.C. equipment an additional set of trolley wires which would not interfere with the D.C. trolleys.

The D.C. trolley hangs in the middle of the track, while the A.C. trolley is on the side of the track, as shown in Fig. 9. The A.C. trolley is suspended from a catenary, consisting of a $\frac{3}{8}$-inch steel cable hung over porcelain insulators fastened to wooden cross-arms (Fig. 10). The trolley is clipped to the catenary midway between the poles, giving an excellent mechanical construction and high insulation. The trolley consists of grooved copper wire, and is fed with 2,200 volts A.C. at twenty-five cycles (the standard frequency in America for transmission and power).

The car is equipped with four compensated series motors, each rated at 50 H.P., a transformer, air compressor, etc., and weighs 30·4 tons without passengers. The motors are of

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the compensated series type; each consists of an annular laminated iron field with a distributed winding similar to that of an induction motor, together with an armature similar to that of a D.C. motor. These motors are wound for 200 volts A.C. and can be used by changing the field connections (the fields are in two sections) with 250 volts D.C. Two of these motors are permanently connected in series, and are fed either at 400 volts A.C. or 500 volts D.C.

On account of the fact that the car runs for one part of its journey with A.C. and for the other part with D.C., it was necessary to have two trolley poles, one in the middle for D.C. and one at the side for A.C. working. The A.C. trolley base rests on insulators. The high potential trolley wire is taken through brass pipes (which are carefully earthed) to one side of the primary of an 80-k.w. air-cooled transformer; the other side of the primary is earthed, as the track is used for the return circuit.

Rheostat control is used; part of the resistance is, however, cut out when working A.C., as the self-induction of the rheostats would be too large. The series parallel controller used is the well-known General Electric K-28. A commutating switch is used in connection with the controller; this changes the field connections, the air-compressor connections, cuts out the transformer, changes the resistance, etc., when changing from A.C. to D.C. running.

The commutating switch is interlocked with two main oil switches, one being in the high-tension A.C., and the other in the 500-volt D.C. circuit; this interlocking is so arranged that only one switch can be closed at a time, and the commutating switch can only be thrown over when the oil switches are in the off position. This interlocking arrangement is necessary on account of the fact that there are two trolley poles, and it prevents trouble in case both trolley poles should accidentally be up.

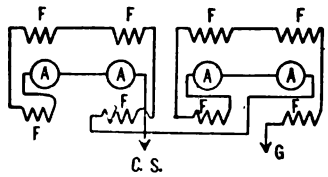
The brakes for the car are operated by air, which is supplied by means of an air-compressor driven by a compensated series motor. The car is geared for about forty-five miles an hour; and on interchanging the field connections it runs at about the same speed whether with A.C. or with D.C. The lights in the car are supplied from a small 7-k.w. oil-cooled transformer.

As I have already stated, two motors are permanently in series; we may therefore consider the control as that of two motors (Fig. 11).

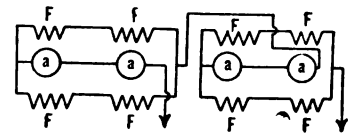
Naturally the control is effected on the low potential side, so that the motorman does not handle any high voltage. The power factor of the motor is fairly good, about 0·9 at full load.

The efficiency, including gear and friction, is, at full load, about 76 per cent. when running A.C., and 80 per cent. when running D.C. When running A.C., the commutation of the motors is good, but they spark a little at starting; when running D.C., the commutation is perfect.

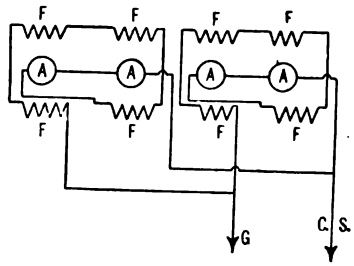
The following are some tests which were



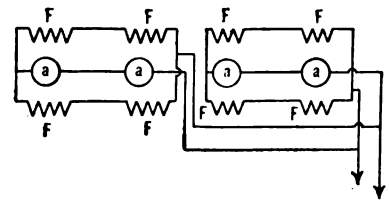
Full series, D.C.



Full series, A.C.



Full parallel, D.C.



Full parallel, A.C.

FIG. 11.—TO ILLUSTRATE METHOD OF MOTOR CONTROL.
A, *armature*. F, *field*. C.S., *commutating switch*.

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conducted in order to compare the acceleration of the motors when running A.C. and when running D.C. All speed-time runs on the Ballston line were made over a distance of 1·6 miles on the level at an average speed of 32 miles per hour, or at a schedule speed of 29·5 miles per hour, including 15-second stops.

DIRECT AND ALTERNATING CURRENT RUNS.*

	Direct.	Alternating.
Length of run in miles . .	1·6	1·6
Weight of car in tons . .	31·55	31·55
Time, seconds	180	180
Average current in amperes.	229	346
Average voltage	606	425
Watts, full speed on level .	98	110
Watt-hours per ton mile .	86·3	125·5
Average speed (M.P.H.) .	32	32
Schedule speed, including 15 sec. stop	29·5	29·5

From these figures we see that when running D.C. the motors are more economical than when running A.C.

The acceleration of the motors when running A.C. is very slow during the first 5 sec., but after this time they accelerate very rapidly.

Everything on the car is carefully earthed, so as to make accidents due to shocks almost impossible.

The low potential side, as well as the high potential side, are protected by fuses. The high potential fuses are placed on the roof of the car.

The car has been in daily service since August 16th, and has given perfect satisfaction. The changing over from D.C. to A.C. running, and *vice versâ*, takes only a few seconds.

The successful operation of this car has demonstrated the fitness of the series motor to meet the severe requirements for urban and inter-urban service on either A.C. or D.C. supply. The cars equipped with A.C. series motors are able to run over existing city tracks without in any way interfering with the running of the existing D.C. cars.

The series motor, having demonstrated its fitness for traction work on urban and inter-urban mixed service, opens up possibilities in converting main line steam roads to electric traction, which would be impossible with the direct current motor and rotary converter combinations, on account of the high first cost and cost of operation.

The commercial development of the A.C. motor is coming at the right moment, as steam railroad managements throughout the world are displaying great activity in electrically equipping portions of their systems, now operating at a loss with steam locomotives.

* *Electrical World*, Vol. 44, p. 332. See also *Electrician*, Vol. 53, p. 826.

SUBMARINE SIGNALLING.

IN foggy weather acoustic signals have long been used to warn ships of the proximity of rocks or sandbanks; but the fact that the atmosphere is not usually homogeneous has led to considerable difficulties and, occasionally, to loss of life. In a paper read before the Institution of Naval Architects, on April 14th, Mr. J. B. Millet describes the development of a system by which acoustic signals can be transmitted to a ship through the sea itself. Since the sea is homogeneous, sounds can be transmitted through it without any of the difficulties which attend their transmission through air. It has been found that a bell with a "lip" several inches thick, which emits a high musical note when struck, forms the best transmitter. This bell is submerged at a depth of about 60 feet below the surface of the sea, and is operated by electricity or compressed air. A closed tank filled with a dense liquid is bolted to the inner side of the plates of the ship below the water-line, and a microphone is immersed in this liquid. On applying one's ears to telephones included in the microphone circuit, the ringing of the transmitting bell can be easily heard even at a distance of several miles in stormy weather. If two tanks are fitted to a ship, one on each of the bows, the direction from which the signals are received can be determined with considerable accuracy. In proof of the practicability of this system, Mr. Millet states that by its aid the captain of the *James S. Whitney* was able to determine his position relatively to a dangerous point on the Nantucket shoals, in a heavy gale and snowstorm at night. He had neither heard nor seen anything for five hours; his soundings indicated a lee shore, and, under favourable conditions, the lightship syren might have been heard, but the gale carried the blast in the opposite direction. The ringing of a submarine bell mounted over the shoal was distinctly heard directly the observer placed his ears to the receiving telephones, and the course of the ship was at once correctly laid; the distance of the ship from the shoal was about five miles. It has been proved that gales, tides, and high winds have no effect on the distance to which the submarine signals can be transmitted.

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BOOSTERS.

PART V.

By HAROLD H. BROUGHTON.

STORAGE BATTERIES.

THE great demand during the past ten years for heavy station-type cells, capable of giving high rates of discharge for short periods with a minimum amount of attention, has been met with promptitude by the manufacturers, and at the present time one finds it difficult to make a choice from the many excellent cells on the market. Seeing that the makers undertake to keep the battery in good condition at a low annual cost, the question resolves itself into one of minimum initial capital outlay.

A common mistake made by English engineers is to put down a battery of quite inadequate dimensions; this is rather surprising, seeing that the cost of a battery, amply large enough, is very small compared with the total cost of the station.

The reader will readily understand that it is beyond the scope of the present articles to describe in detail the various types of cells, and their housing. It will be sufficient if we give a few general notes on the management of batteries, and briefly consider the construction and arrangement of one or two types.

The battery attendant should follow the instructions given below, which apply equally to all types of cells, and are independent of the nature of the load carried by the battery.

First Charge.—During, and especially towards the end of the charge, the battery room should be well ventilated. Each charge should be continued until both positive and negative plates "gas" freely, and the attendant ought to satisfy himself personally, towards the end of each charge, that every individual cell begins to gas evenly and at the same time as all the others; should some of the cells gas slowly or insufficiently, they must immediately be inspected with a view to detect any short circuits between the plates. The cells may be inspected by means of a low voltage lamp suitably mounted in a flat tube of insulating material through which the flexible leads are carried. Mr. Turnbull, in his paper previously referred to, recommends that the battery room should be rather dark, with good artificial lighting, in order to render the inspection of the cells easy. If short circuits are discovered, and it is impracticable to remove these at once, the faulty cells should be cut out of circuit by special leads kept for the purpose.

Discharging and Charging. — When the pressure of the battery falls below 1·8 volts per cell, while the cells are discharging at a normal rate, the battery should be considered discharged, and no more current taken out. If the cells are used with lower currents, or are standing idle, the voltage will not be a safe criterion with reference to the state of the battery, and readings of the density of the acid should be taken, as this is approximately proportional to the state of the charge. The difference in specific gravity between full charge and discharge is approximately 0·012, and any intermediate reading will show how far the cells are discharged; and when the battery is used as a booster it is advisable to take the specific gravity of the acids, together with voltmeter readings, at frequent intervals in order to ascertain whether the cells have meanwhile been charged or discharged, and to get a good idea of the state of each cell.

The type of cell shown in Fig. 37, made

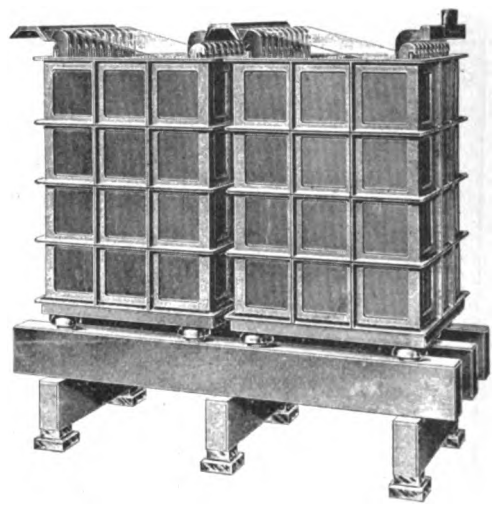

FIG. 37.—CENTRAL STATION CELL, O.K. TYPE. (Electrical Power Storage Company.)

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by the Electrical Power Storage Company, and known as the O.K. Type Central Station cell, has been designed to meet the demand for a heavy and trustworthy cell for lighting and traction stations. The cell has capacity for high rates of discharge—1,000 amperes for one hour from ten positive plates, as a maximum. The box consists of a lead alloy crate with lead lining, provided with a lip, so that leakage due to "creeping" cannot take place, thus making the box absolutely indestructible. The construction is such that each plate can be separately removed without interference with the remainder or with the circuit, and the massive connections leave little to be desired. The makers claim an increased economy of floor space for this type of cell—a battery of O.K. cells occupying only about 5·6 square feet of floor space per kilowatt hour. The method of supporting and insulating the cells will be understood from the figure.

Table I. gives further particulars of these cells.

The Hart Accumulator Company has recently completed a battery of 260 cells for the Bradford Corporation, having a capacity of 1,360 ampere-hours at the ten hour discharge rate, the maximum discharges being 750 amperes for one minute peaks, with 500 amperes for periods of one hour. The boxes are made of lead, lipped at the top, with strengthening wood battens at the sides, and a lead eave is burned all round the boxes to catch the drippings from the top, caused by acid spray, and so on. The boxes are placed on trays, which in turn rest on insulators, the stands being made of pitch pine thoroughly well coated with anti-sulphuric enamel. The separators are of glass, nine-sixteenths of an inch in diameter; with this space between the plates there is no danger of internal short circuits. Six inches is allowed below the plates for the accumulation of deposit, and as this is sufficient for many years work, it obviates the necessity of periodical cleaning, which is always inconvenient.

There are 17 positive and 18 negative plates per cell, the dimensions being 9·25 inches by 11·5 inches, and 9·5 inches by 12 inches respectively. The weight of each cell complete with electrolyte is 847 pounds.

The capacity at various discharge rates is given below, the electromotive force in each case not falling below 1·80 volts per cell at the end of discharge.

Discharge Rate.	Capacity.
400 amperes	700 ampere hours
300 ,,	750 ,,
200 ,,	1,000 ,,
100 ,,	1,400 ,,

This battery is intended to run in series with one of the Lancashire Dynamo and Motor Company's automatic reversible boosters, and will work in parallel with the main generators of the traction-station.

Before bringing the notes on rotary boosters to a close, it is desirable that we should say a few words on the testing of these machines.

TABLE I.—PARTICULARS OF O.K. CELLS.

Number of Plates.	Maximum Charge.	Discharge Amperes.			Approximate Dimensions.						Weight of Cell complete with acid.	Pitch of Cells.		Insulator Centres.		Bearer Centres.	Number of Bearers.
		1 hour.	3½ hours.	7 hours.	Length.		Width.		Depth.								
					ft.	ins.	ft.	ins.	ft.	ins.	lbs.	ft.	ins.	ft.	ins.	ins.	
9	200	400	220	140	1	11	0	11¾	2	10½	717	2	0	1	3	7	2
11	250	500	275	175	1	11	1	1¾	2	10½	850	2	0	1	3	7½	2
13	300	600	330	210	1	11	1	3½	2	10½	985	2	0	1	3	8½	2
15	350	700	385	245	1	11	1	5½	2	10½	1125	2	0	1	3	9½	2
17	400	800	440	280	1	11	1	7¼	2	10½	1265	2	0	1	3	7	3
19	450	900	495	315	1	11	1	9	2	10½	1400	2	0	1	3	7½	3
21	500	1000	550	350	1	11	1	11	2	10½	1535	2	0	1	3	8	3
23	550	1100	605	385	1	11½	2	1	2	10½	1670	2	0½	1	3	8½	3
25	600	1200	660	420	1	11½	2	3	2	10½	1805	2	0½	1	3	9½	3
27	650	1300	715	455	1	11½	2	5	2	10½	1935	2	0½	1	3	10	3
29	700	1400	770	490	1	11½	2	7	2	10½	2070	2	0½	1	3	8	4
31	750	1500	825	525	1	11½	2	9	2	10½	2200	2	0½	1	3	8½	4
33	800	1600	880	560	1	11½	2	11½	2	10½	2330	2	0½	1	3	9	4
35	850	1700	935	595	1	11½	3	1½	2	10½	2460	2	0½	1	3	9½	4
37	900	1800	990	630	1	11½	3	3½	2	10½	2590	2	0½	1	3	10	4
39	950	1900	1045	665	1	11½	3	6	2	10½	2720	2	0½	1	3	10½	4
41	1000	2000	1100	700	1	11½	3	8	2	10½	2850	2	0½	1	3	11	4

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Seeing that boosters have a very important duty to perform in lighting and traction stations, the determination of their efficiency, output, and behaviour becomes of considerable importance.

Briefly stated, the test may be divided into two parts :—

(*a*) Rise of temperature test.

(*b*) Efficiency test.

(*a*) The best method of determining the temperature rise is to obtain the resistances of the armature and field coils cold, and to run the machine at full load for six hours, and again determine the resistances. Remembering that the resistance of copper

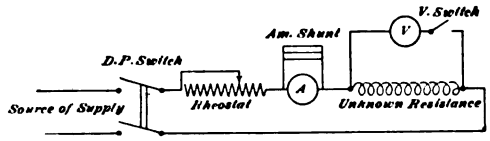

FIG. 38.—DIAGRAM OF CONNECTIONS FOR DETERMINING THE TEMPERATURE RISE OF ARMATURE AND FIELD COILS.

increases by 0·21 per cent. per degree Fahrenheit rise of temperature, the temperature rise can be at once determined.

The resistance may be readily measured by means of a milli-amperemeter, and millivoltmeter, the diagram of connections being shown in Fig. 38. In quick succession about twenty readings of A and V should be taken by adjusting the rheostat, and the resistance calculated from the R = V/A formula, the average of the whole of the readings being regarded as the correct resistance. With good instruments this method, in the hands of a careful man, yields exceedingly accurate results, as will be seen from Table II., taken at random from a student's note-book. Standard instruments by Nalder Bros. and Thompson were used for reading the current and voltage, and current was supplied by a low voltage generator, the excitation being varied as the test proceeded. A permanent water resistance was used to bring down the current to a low figure, and the whole of the regulation was effected by varying the excitation of the generator. The figures given in the table are from a run of one and a half hours at full load, and the 38° F. must not be regarded as the working temperature, as the temperature rises steadily for about five hours.

TABLE II.—RISE IN TEMPERATURE OF THE ARMATURE OF A 6 K.W. GENERATOR.

Cold.			Hot.		
Amps.	Volts.	Ohms.	Amps.	Volts.	Ohms.
8·95	2·90	0·324	1·68	0·590	0·351
7·61	2·45	0·322	1·66	0·585	0·352
6·50	2·10	0·323	1·84	0·648	0·351
4·95	1·60	0·324	1·88	0·658	0·350
4·20	1·35	0·322	2·00	0·700	0·350
7·10	2·30	0·324	2·20	0·772	0·350
7·77	2·49	0·322	2·48	0·873	0·351
8·24	2·65	0·322	3·12	1·100	0·352
9·90	3·20	0·323	3·55	1·250	0·352
11·00	3·55	0·323	4·16	1·470	0·353
12·20	3·98	0·322	3·12	1·100	0·352
9·95	3·33	0·325	3·55	1·250	0·352
Mean resistance = 0·323 ω			Mean resistance = 0·351 ω		

Increase of resistance = 0·028 *w* ; Percentage increase = 8 %. Since for every 0·21 per cent. increase of resistance the temperature rises 1° F., the rise in temperature equals = 8/0·21 = 38·1° F.

(*b*) The elementary diagram of connections for the efficiency test in a simple case is given in Fig. 39. M, D is the motor generator, E is a source of electrical energy ; A_m, A_d, a_m and a_d ammeters ; V_m and V_d voltmeters ; R_m, R_d, and r_m adjustable rheostats ; S_m, S_d, and s_d switches.

The method of conducting the test is as follows :—

1. With all the switches open, increase R_m and R_d to the maximum value, and make r_m a minimum.

2. Close S_m and run the motor up to normal speed N, by adjusting R_m. Note

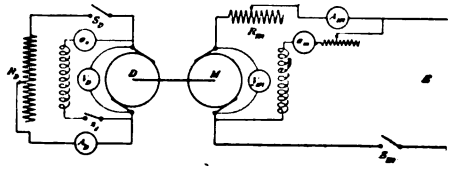

FIG. 39.—DIAGRAM OF CONNECTIONS FOR EFFICIENCY TEST.

simultaneously the readings of all the instruments, and the speed N.

3. Close s_d, so allowing the generator to build up its field, and then close S_d, and adjust the rheostat R_d so that A_d reads about one-tenth of full load current, keeping the speed constant by adjusting r_m if necessary. Again read all the instruments.

4. Repeat (3) for about ten different load currents A_m, up to 1·25 full load, rising by about equal increments, and tabulate the readings as follows :—

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TABLE III.—SKELETON MODEL FOR TABULATING RESULTS OF EFFICIENCY TEST.

Maker..... Date.....

Machine No..... Type..... Normal Output :—Volts..... ; Amperes..... ; Watts..... ;
Speed..... Resistance of Motor Shunt Coil = ... ω. Resistance of Generator Shunt Coil = ... ω.
Resistance of Motor Armature = ... ω. Resistance of Motor Armature over Brushes = ... ω.
Resistance of Generator Armature = ... ω. Resistance of Generator Armature over Brushes = ... ω.
Additional Information.....

Speed N.	Motor. Shunt Current a_m.	Motor. Watts used in Shunt $a_m^2 r_m$.	Motor. Current A_m amperes.	Motor. Volts V_m.	Motor. Watts $A_m V_m$.	Motor. Total Input $W_1 = A_m V_m + a_m^2 r_m$.	Generator. Shunt Current A_g.	Generator. Watts used in Shunt $a_g^2 r_g$.	Generator. Current A_g amperes.	Generator. Volts V_g.	Generator. Net Output of Generator $W_2 = (A_g V_g)$.	Efficiency of Motor Generator $E = \frac{W_2}{W_1} \times 100$ %.

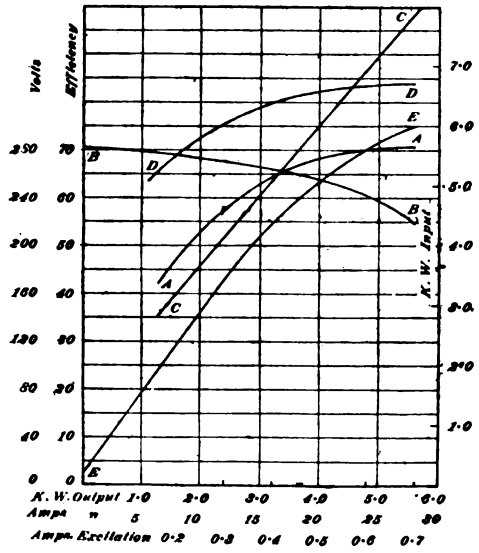

FIG. 40.—TEST CURVES, SHUNT WOUND MOTOR GENERATOR.

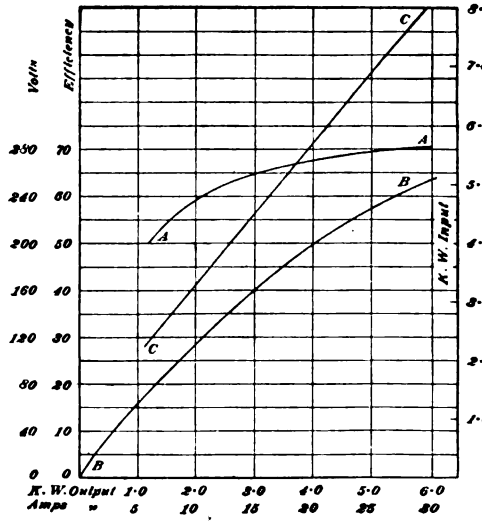

FIG. 41.—TEST CURVES, SERIES WOUND MOTOR GENERATOR.

Shunt wound motor, 230 *volts*, 1,150 *r.p.m.*

AA, *Efficiency of combination.* CC, *Useful output in terms of motor input.*
BB, *Generator characteristic.* DD, *Efficiency of motor.*
EE, *Generator saturation curve.*

The efficiency curve may now be obtained by plotting W_2 horizontally and E vertically. The generator characteristic may be obtained by plotting V_g vertically and A_m horizontally. Further, each of the losses may be plotted vertically and the output horizontally.

The curves shown in Figs. 40, 41, and 42 are the plotted results of a series of tests made in the writer's laboratory at the Brighton Technical Schools. The set consists of two identical machines made by the Lancashire Dynamo and Motor Company, especially arranged for testing purposes. The windings allow of the machines being run shunt, series, or compound, a diverter in parallel with each series field, and a resistance in series with each shunt winding giving a wide range of excitation. The machines may be loaded either by means of a forty-point wire rheostat, or a water resistance, or a lamp-bank resistance; the connections to the various rheostats being made on a distribution board, which

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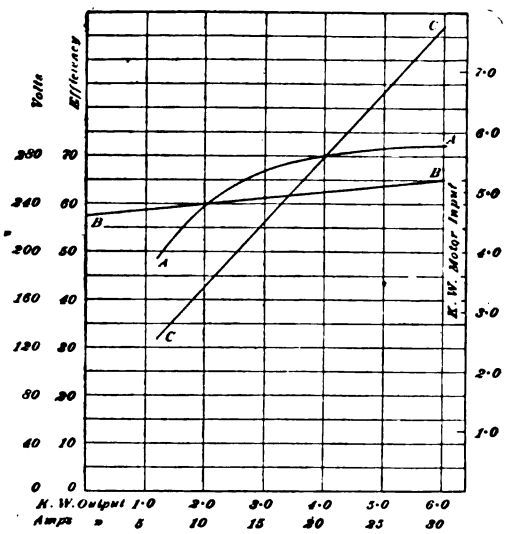

FIG. 42.—TEST CURVES, COMPOUND WOUND MOTOR GENERATOR.

Shunt wound motor, 230 volts, 1,150 r.p.m.

AA, *Efficiency of combination.*

BB, *Generator characteristic.*

CC, *Useful output in terms of motor input.*

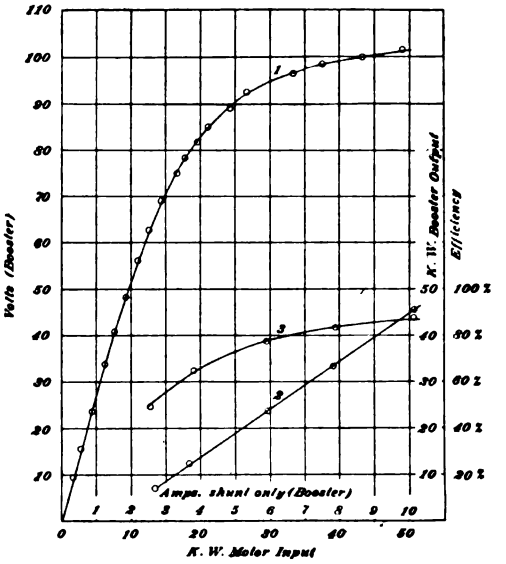

FIG. 43.—TEST CURVES, 40 K.W. AUTOMATIC REVERSIBLE BOOSTER (THURY).

650 *to* 750 *r.p.m.*

Curve 1.—*No-load volts of booster on one commutator, with shunt excitation only.*

Curve 2.—*Useful output of booster, in terms of motor input.*

Curve 3.—*Combined efficiency in terms of motor input,*

TABLE IV.—DETAILS OF EFFICIENCY TEST.

Maker.—Lancashire Dynamo and Motor Co., Ltd. *Date.*—March 21st, 1905.

Machine Nos.—Motor, 3241; Generator, 3240. *Type.*—Four pole, direct coupled.

Normal Output.—230 volts; 26 amperes; 6000 watts; 1150 revolutions per minute.

Resistances

Motor.—Armature cold = 0·323 ω; Armature hot = 0 351 ω. Brush Resistance = 0·041 ω.
Shunt winding cold = 431·3 ω. Shunt winding hot = 476·8 ω.

Generator.—Armature cold = 0·329 ω; Armature hot = 0·350 ω. Brush Resistance = 0·029 ω.
Shunt winding cold = 425·0 ω. Shunt winding hot = 466·0 ω.

Speed N revs. per minute.	Motor.						Generator.					Efficiency of Motor Generator $E = \frac{W_2}{W_1} \times 100$%	Efficiency of Motor $\Sigma = \sqrt{E}$
	Shunt Current A_m.	Watts used in Shunt $= a_m^2 r_m$.	Armature Current A_m.	Volts V_m.	Watts $A_m V_m$.	Total Input $W_1 = (A_m V_m + a_m^2 r_m)$.	Shunt Current A_g.	Watts used in Shunt $a_g^2 r_g$.	Current A_g.	Volts V_g.	Net Output of Generator $W_2 = A_g V_g$.		
1150	0·49	115	7·1	235	1668	1783	0·6	167	—	283	—	—	—
1150	0·49	115	8·8	235	2075	2190	0·6	167	2·1	281	590	27·0	52·0
1150	0·49	115	18·5	235	4345	4460	0·58	156	9·9	270	2670	60·0	77·5
1150	0·49	115	21·1	235	4965	5080	0·59	162	12·5	268	3350	65·0	80·6
1150	0·49	115	24·2	235	5685	5800	0·54	136	14·8	264	3900	67·0	82·0
1150	0·49	115	25·8	235	6005	6120	0·56	146	15·7	265	4150	68·0	82·5
1150	0·49	115	27·6	235	6475	6590	0·53	130	17·5	260	4540	69·0	83·1
1150	0·49	115	31·3	235	7345	7460	0·52	126	20·6	255	5253	70·5	84·0
1150	0·49	115	33·5	235	7885	8000	0·52	126	23·0	246	5658	70·9	84·2
1150	0·49	115	34·1	235	8005	8120	0·51	121	24·0	242	5800	71·5	84·6
1150	0·49	115	34·8	235	8175	8390	0·50	116	26·0	230	5980	71·5	84·6
1150	0·49	115	36·8	235	8605	8720	0·49	112	28·0	221	6188	71·0	84·4

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latter is common to all the machines in the laboratory.

The whole of the connections are permanent, the arrangement of the switch gear being such as to allow the changes to be effected without interfering with the machine connections in any way. In a college laboratory this is undoubtedly the better plan, provided students make themselves thoroughly conversant with the switchgear before testing the machines.

The normal speed of the machines is 1,150 revolutions per minute on 230 volts, though the speed may be regulated between very wide limits by means of resistances in the armature and field circuits. For lower voltage working, spare armatures for 115 volts are provided.

In the tests referred to above, the generator was loaded up on a water resistance, the output being determined by means of a standard testing set by Nalder Brothers and Thompson. The speed of the motor was kept constant by altering the field excitation, readings being taken with the tachometer. The rise of temperature was determined by the increase of resistance methods, the resistance being measured, immediately before and immediately after the test, by the fall of potential method. The results of the test plotted in Fig. 40 are tabulated in Table IV.

The various losses were determined in a separate series of tests, and want of space prevents us from entering into details of these. The interested reader cannot do better than refer to any of the numerous treatises on electrical engineering testing for further information.

The test curves of the Thury booster, described in a previous article, are given in Fig. 43, and require no description.

Fig. 44 illustrates, in a striking manner, one of the ills to which this class of machinery, in common with all rotatory appliances, is subject; how the central station engineer swallowed this bitter experience had best be left to the imagination of the reader.

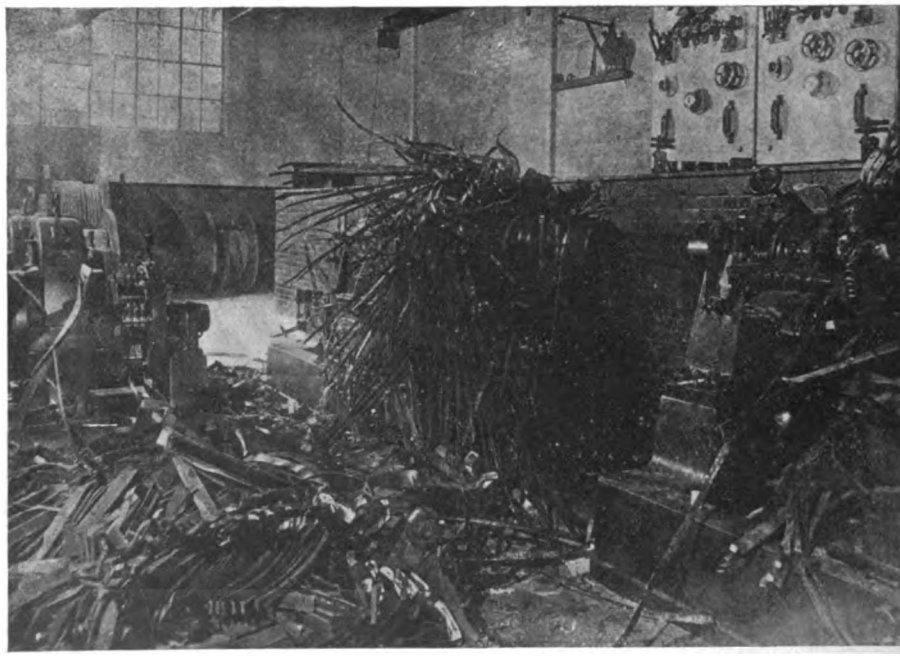

FIG. 44.—RESULT OF ACCIDENT TO ROTARY BOOSTER.

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART IX.—ELECTRONS (*continued*).

By EDWIN EDSER, A.R.C.Sc.

IN the May number of TECHNICS (pp. 421–428) I gave a brief account of a theory, by the aid of which the properties of a moving charged sphere can be explained. I also showed how this theory has been applied to explain the phenomena which occur in a vacuum tube during the passage of an electric current. One of the most important conclusions reached was that the kathode rays in a vacuum tube consist of streams of negatively charged particles, the mass (or inertia) of each particle being equal to about one seven-hundredth part of the mass of a hydrogen atom, while the charge is equal to that carried by a hydrogen atom in electrolysis: these ultra-atomic particles are now known as *electrons*. In the present article I propose to give a short account of the experiments performed, and the conclusions reached, with regard to electrons derived from sources other than the kathode rays. In the first place, it will be advisable to describe the rays first observed by Lenard, and known as the Lenard rays.

Lenard Rays.—As explained in the last article, kathode rays are intercepted by most material bodies, even by a thin film of mica or glass; this is proved by the fact that such films throw well-defined shadows when interposed between the kathode and the walls of a vacuum tube (TECHNICS, Vol. III., No. 17, May, 1905, p. 426). Hertz found, however, that *very thin* films of gold or aluminium (films not more than a few thousandths of a millimeter thick) are apparently transparent to kathode rays; they do not cast perfectly dark shadows, as thicker films would. Lenard followed up this discovery by making a vacuum tube with a small aperture or window in its walls, 1·7 mm. in diameter, closed with a film of aluminium 0·00265 mm. thick; the tube was highly exhausted, and the rays from the kathode were allowed to fall on the inside of this window, when it was found that they apparently passed through the film of aluminium and emerged into the air, causing the latter to become luminous for a distance of a few centimeters from the window. Phosphorescent substances, such as zinc sulphide (blende) or barium platinocyanide, became luminous when placed near the window. If the space beyond the window, instead of being occupied by air at atmospheric pressure, is highly exhausted, the rays leaving the window travel much farther. These rays have been called *Lenard Rays*. Lenard found that the opacity of a substance to these rays is proportional to the density of the substance.

Lenard rays are deflected by magnetic and electric fields in a manner precisely similar to that observed in connection with kathode rays; hence we conclude that Lenard rays consist of streams of negatively charged particles travelling with considerable velocities. Lenard conducted an experiment in which these rays simultaneously traversed electric and magnetic fields arranged so as to deflect the rays in opposite directions (compare TECHNICS, Vol. III., No. 17, May, 1905, p. 428), and adjusted the strengths of these fields so that no deflection was produced; thus, in a manner similar to that already explained in connection with kathode rays, the velocity of the Lenard rays was found to be equal (on an average) to 7×10^9 cms. per second. On determining the curvature of the path of these rays under the sole action of a magnetic field, and substituting in the appropriate formula (TECHNICS, Vol. III., No. 17, May 1905, equation (5), p. 427) the ratio of the charge q to the mass (or inertia) m of a particle was found to be equal to about $6{\cdot}4 \times 10^6$—a result in good agreement with that found for the kathode ray particles, *i.e.*, $7{\cdot}7 \times 10^6$. Hence we conclude that Lenard rays consist of streams of electrons, similar to kathode rays; indeed, we may fairly assume that Lenard rays are merely kathode rays which have traversed a thin film of metal forming a window in a vacuum tube, and so have emerged into the atmosphere.

Electrons produced by the Action of Ultra-Violet Light.—It has been found that when ultra-violet light falls on a negatively-charged

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zinc plate, the charge of the plate rapidly falls; this result suggests that, under the action of ultra-violet light, electrons are given off from the zinc. These electrons act as the carriers by means of which the negative charge is transported from the plate. Once an electron has escaped from the negatively-charged plate, it will be repelled, and will move away from the plate with an increasing velocity, provided that its movement is not interfered with by the surrounding gas. If the plate is enclosed in an exhausted vessel, the electrons will quickly acquire considerable velocities, and if they traverse a magnetic field at right angles to their direction of motion, their paths will become curved.

Professor J. J. Thomson has utilised these principles in order to determine the ratio of the charge to the mass of the particles emitted

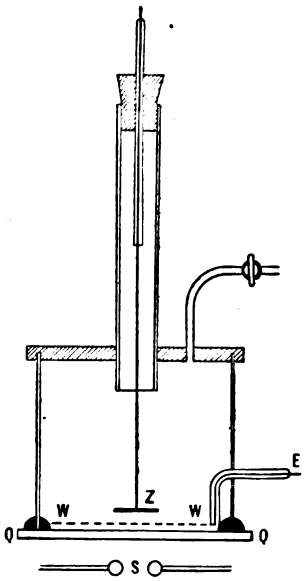

FIG. 1.
APPARATUS FOR INVESTIGATING THE PROPERTIES OF THE ELECTRONS GIVEN OFF FROM A ZINC PLATE UNDER THE ACTION OF ULTRA-VIOLET LIGHT.

from a zinc plate under the action of ultra-violet light. A zinc disc Z (Fig. 1) is enclosed in a vessel from which the air is exhausted as completely as possible, and is supported by a rod connected with the negative terminal of a powerful battery. W W represents a piece of wire gauze connected to an electrometer by means of the connecting wire E. The lower end of the containing vessel is covered with a plate of quartz Q Q, which is transparent to ultra-violet light. When a series of sparks are caused to pass between the zinc knobs S, the ultra-violet light from these sparks traverses the quartz plate Q and the wire gauze W W, and falls on the zinc disc Z: electrons are emitted by Z, which move downwards and fall on the wire gauze W W, thus giving a negative charge to the electrometer, or discharging the electrometer if the charge of the latter is positive.

A magnetic field is now produced in the space between Z and W W; let us suppose

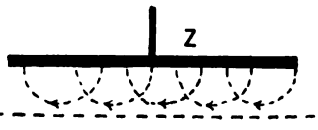

FIG. 2.—DETAIL OF FIG. 1, SHOWING PATHS OF ELECTRONS.

that the lines of force pass vertically downwards through the plane of the paper in Fig. 1. Then, as the velocity of an electron increases, so will the electro-magnetic force acting on it increase, with the result that the electrons traverse cycloidal paths and ultimately return to the zinc disc (Fig. 2). The radius of the generating circle of the cycloid depends on the known values of the electric field F between Z and W, the magnetic field H at right angles to the path of the particles, and the mass m and charge q of each particle; the value of the radius of this circle can be shown* to be equal to $(m\ F) / (q\ H^2)$, and since the diameter of the generating circle is equal to the distance from the zinc disc Z at which an electron commences to return to the disc, it follows that if the distance from Z to W W is greater than $(2\ m\ F) / (q\ H^2)$, no electron will reach W W, and the electrometer will be unaffected; for smaller distances between Z and W W, the positive charge of the electrometer will be quickly dissipated. The actual phenomena are not so abrupt as this theory indicates. It is found in practice that when Z and W W are near together the magnetic field produces only an exceedingly small effect. On increasing the distance from Z to W W, a stage is reached at which the magnetic force produces a very great effect on the charging or discharging of the electrometer. At still greater distances the magnetic field has so great an effect that the electrometer maintains the same deflection whether the ultra-violet light falls on the disc Z or not.

* "Conduction of Electricity through Gases." By J. J. Thomson, LL.D., F.R.S., etc. (University Press, Cambridge. 1903). p. 88.

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Professor J. J. Thomson observed the distance d from the disc Z to the wire gauze W W when the magnetic field H begins to retard the effect on the electrometer; then from the equation

$$d = (2\ m\ \mathrm{F}) / (q\ \mathrm{H}^2),$$

in which all quantities except m and q were known, the value of the ratio q/m was calculated; this was found to be equal to $7 \cdot 3 \times 10^6$ which is in remarkably close agreement with the corresponding value for kathode rays.

Electrons emitted by a heated body.—An intensely heated body loses a negative charge very quickly, a result which indicates that heated bodies emit electrons. Professor J. J. Thomson determined the ratio q/m for these electrons when the heated body is an incandescent carbon filament in rarefied hydrogen; a magnetic field was produced in a direction perpendicular to the path of the electrons leaving the filament, and the distance from the filament to which the electrons then travelled was determined in a manner practically similar to that already described in connection with the electrons emitted under the action of ultra-violet light. The value found for the ratio q/m was $8 \cdot 7 \times 10^6$.

Radium Radiations.—The element radium emits a number of radiations which may be classified as follows:—

The α rays are perceptibly deflected in a magnetic field only when this is of very great strength: the direction of their deviation in strong magnetic fields indicates that they consist of streams of positively charged particles. α rays are very easily absorbed, and can only travel a few millimeters through air.

The β rays are readily deviated by a magnetic field; the direction of their deviation indicates that they consist of streams of negatively charged particles. β rays are very penetrative, and can pass through thin layers of glass, mica, aluminium, etc.

The γ rays cannot be deflected in the strongest magnetic fields which have been obtained up to the present; hence these probably do not consist of streams of charged particles, but of some form of ætherial disturbance more or less akin to light.

The fact that a thin layer of aluminium or glass suffices to stop the α rays, while the β and γ rays are allowed to proceed, gives us a means of getting rid of the α rays. When the β rays of radium pass through air, they ionise the air, or render this conducting; probably the β ray particles strike against the atoms or molecules of the air, and cause electrons to be emitted in much the same way as when ultra-violet light falls on zinc. This fact renders it impossible to charge a body negatively by allowing β rays to fall on it, unless special precautions are taken to prevent the ionised air from coming in contact with the body. M. and Mme. Curie proved that β rays, when they fall on a body, communicate a negative charge to the latter, in the following way:—A disc of lead was entirely enclosed in a block of paraffin wax, the latter being coated all over its exterior surface with a layer of aluminium foil connected to the earth. The lead disc was connected by an insulated wire with an electrometer. When some radium was placed near the block of paraffin wax, the β and γ rays penetrated the aluminium coating and the wax, and reached the lead disc; here the β rays were stopped and gave up their negative charges, with the result that the electrometer acquired an increasing negative charge. The α rays were unable to penetrate the aluminium, and therefore never reached the lead disc; the air ionised by the radium never came in contact with the lead disc, but only with the earth-connected aluminium coating of the wax, and therefore produced no effect on the result.

The deviation of the β rays by a magnetic field was discovered simultaneously by several observers; an account will now be given of the method used by Becquerel to observe the deviation, and to determine the ratio of the charge to the mass of the particles. A rectangular block of lead L (Fig. 3) has a vertical saw-cut S made in one of its faces, and some radium is placed in the bottom of this cut. The radiations leaving the orifice of the cut issue nearly parallel to each other, and if they fall on the surface of an inclined sheet of glass P coated with some phosphorescent substance, a luminous line will be traced where the rays fall. If P is a photographic plate, the rays will reduce the silver salts at the points on which they fall, and after development the plate will exhibit a dark

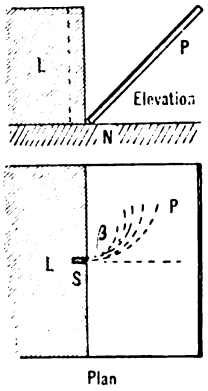

FIG. 3. — TOILLUSTRATE BECQUEREL'S METHOD OF SHOWING THE DEFLECTION OF THE β RAYS OF RADIUM.

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band (the central band in Fig. 4). In this case the mouth of the saw-cut must be covered by a thin lamina of aluminium, so as to intercept the light from the phosphorescent radium.

Now let us suppose that the block of lead is placed on the pole N of a magnet (Fig. 3), an opposite pole (not shown in the figure) being placed above the block in order to concentrate the field. If N is a North pole, the other pole being South, the β rays are

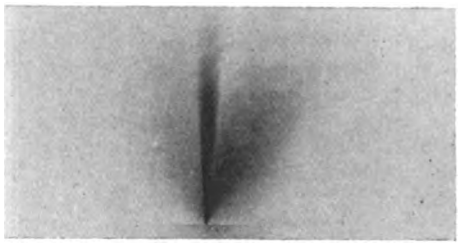

FIG. 4.—PHOTOGRAPHIC PLATE, AFTER EXPOSURE TO RADIATION FROM RADIUM IN MANNER REPRESENTED IN FIG. 3.

twisted to one side and describe curved paths as indicated in Fig. 3; the direction of deflection shows that the β rays consist of negatively-charged particles. On reversing the polarity of the poles, the β rays are deflected toward the opposite side, and the final result obtained when the photograph is developed is shown in Fig. 4.

Kaufmann has succeeded in acting on the β rays of radium simultaneously with an electric and a magnetic field, the direction of these being such that the deflection due to one was in the opposite direction to that due to the other. The whole experiment was conducted in an exhausted vessel, in order to avoid the retarding action of any gas on the β rays; the rays were finally allowed to fall on a photographic plate, so that their resultant deflection could be noted. The deflection due merely to the magnetic field was subsequently observed. Employing the reasoning already explained in connection with kathode rays, it was found that the β rays do not all travel with the same velocity; further, the ratio q/m varied, being least for the rays travelling with the highest velocities. The results obtained by Kaufmann are given in Table I.

It will be noticed that the value of the ratio q/m diminishes as the velocity increases; if we suppose (as seems natural) that q is constant, then this means that the mass (or inertia) of a particle increases as the velocity increases. It will be remembered that this

TABLE I. — VALUES OF v AND q/m FOR β RAYS OF RADIUM.

v (cms./sec.)	$\frac{q}{m}$
$2{\cdot}83 \times 10^{10}$	$0{\cdot}63 \times 10^{7}$
$2{\cdot}72 \times 10^{10}$	$0{\cdot}77 \times 10^{7}$
$2{\cdot}59 \times 10^{10}$	$0{\cdot}975 \times 10^{7}$
$2{\cdot}48 \times 10^{10}$	$1{\cdot}17 \times 10^{7}$
$2{\cdot}36 \times 10^{10}$	$1{\cdot}31 \times 10^{7}$

result might be predicted from theoretical grounds (TECHNICS, Vol. III., No. 17, May, 1905, p. 423); the tubes of force carried by a charged sphere tend to crowd up toward the equatorial plane of the sphere as the velocity increases, and this causes the sectional areas of the tubes to diminish and their inertia to increase. Professor J. J. Thomson has calculated the theoretical ratio of the inertia m_1 of a charged sphere moving with a velocity of the order observed by Kaufmann, to the inertia m of the same sphere when moving with a small velocity, *assuming that the inertia of the sphere is entirely due to the tubes of force carried along with it*; the results are given in Table II., which also gives the values obtained by Kaufmann from experiments.

TABLE II.

v (cms./secs.)	(m_1/m) Theoretical.	(m_1/m) From Experiment.
$2{\cdot}83 \times 10^{10}$	3·1	3·09
$2{\cdot}72 \times 10^{10}$	2·42	2·43
$2{\cdot}59 \times 10^{10}$	2·0	2·04
$2{\cdot}48 \times 10^{10}$	1·66	1·83
$2{\cdot}36 \times 10^{10}$	1·5	1·65

It will be observed that the values of the ratio m_1/m, calculated from theoretical considerations, are in excellent agreement with those obtained from experiment; this suggests that the *mass (or inertia) of an electron is entirely due to the tubes of force associated with it.* In this case the inertia of a slowly moving electron would be equal to $(2q^2)/(3a)$, where a is the radius of the electron, and q its charge in c.g.s. electro-magnetic units; if we assume that the charge q is equal to that carried by a hydrogen atom in electrolysis, we can calculate the value of m from the known value of the ratio q/m, and from this we can obtain a, the radius of the electron (supposed to be a sphere). The value of a obtained is about 10^{-13} c.m., which is much less than the dimensions of an atom (*i.e.*, about 10^{-7} or 10^{-8} c.m.).

The deflection of the α rays in a very

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strong magnetic field was first observed by Rutherford; the method subsequently used by Becquerel to confirm Rutherford's observations will here be described, as it is more direct and easily understood.

A block of lead (L, Fig. 5) was provided with a vertical saw-cut containing radium, just as in the experiment with the β rays (p. 559). A metal diaphragm with a fairly narrow vertical slit was placed directly in front of the saw-cut; on exciting the electro-magnet so that N became a very strong North pole, the β rays were deflected to one side and intercepted by the diaphragm, while the α rays were only slightly deflected, and that in a direction opposite to that of the β rays. Thus the α rays passed through the slit in the diaphragm, and fell on the phosphorescent screen or photographic plate P; on reversing the polarity of the magnet poles the direction of deflection of the α rays was reversed, and the photographic plate showed the two narrow dark lines in Fig. 6, after development.

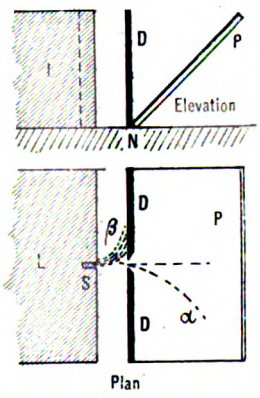

FIG. 5.—TO ILLUSTRATE BECQUEREL'S METHOD OF SHOWING THE DEFLECTION OF THE α RAYS OF RADIUM.

Rutherford concludes that the velocity of the α ray particles is about $2{\cdot}5 \times 10^9$ cms. per second, *i.e.*, less than one-tenth part of the velocity of light. The ratio of the charge q to the inertia m of an α ray particle is about 6×10^3, which is of the same order of magnitude as the ratio of the charge carried by a hydrogen atom in electrolysis to the mass of that atom. All experiments performed up to the present go to show that particles carrying *positive* charges are of ordinary atomic dimensions.

Determination of the charge carried by an Electron.—By the aid of a sensitive electrometer very small electric charges can be accurately measured. Hence, if a space contains a considerable number of electrons, and the charges carried by these can be communicated to an electrometer, their sum can be determined; if the electrons can then be counted, the charge carried by each will become known. At first sight it would appear to be impossible to count the number (amounting to many millions) of electrons in a given space, each electron being far smaller than an atom, and, therefore, far beyond the perception of our senses, even when aided by the best modern microscope; nevertheless, Professor J. J. Thomson has succeeded in this seemingly impossible task, using the method now to be briefly explained.

The surface of a liquid is the seat of a considerable store of energy; the energy per unit area of the surface is called the *surface tension* of the liquid. When a vapour condenses, the corresponding liquid must possess a surface, and must, therefore, possess a store of energy not present in the vapour. Let T be the surface tension of a liquid.

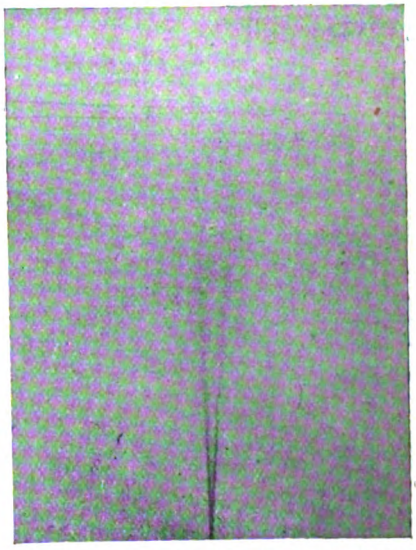

FIG. 6.—PHOTOGRAPHIC PLATE, AFTER EXPOSURE TO RADIATION FROM RADIUM IN MANNER REPRESENTED IN FIG. 5.

The surface of a spherical drop of radius r centimeters will have an area of $4\pi r^2$ square centimeters, and the surface energy of this drop will be equal to $4\pi r^2 T$. Let us suppose that a drop of water of radius r is formed by the condensation of aqueous vapour; the mass of the drop is equal to $(4\pi r^3)/3$, and the energy liberated in the form of heat will be equal to $(4\pi r^3 L)/3$, where L is the latent heat of water. If

$$4\pi r^2 T > \frac{4\pi r^3 L}{3}, \text{ or } r < \frac{3T}{L},$$

the energy liberated by condensation would be less than that required to supply the surface energy of the drop, and therefore condensation would not occur.

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Thus a space may be supersaturated with aqueous vapour, and yet no condensation will occur, owing to the fact that, if it did, drops smaller than the above limit must be initially formed. Aitken has shown that if finely divided solid particles (such as dust or smoke) are present in the space, condensation will occur round these, since each particle can act as a nucleus for the vapour to condense and form a drop initially larger than the above limit. C. T. R. Wilson has found that electrons act as condensation nuclei; in this case the drop formed round an electron will be charged, and the lines of force ex-

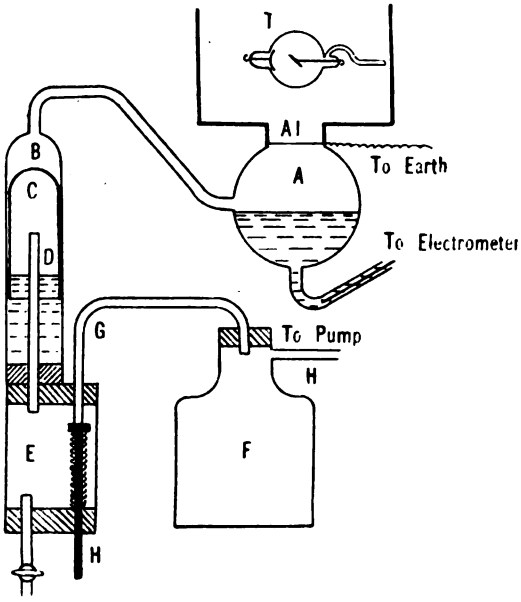

FIG. 7.
TO ILLUSTRATE PROF. J. J. THOMSON'S METHOD OF DETERMINING THE CHARGE OF AN ELECTRON.

tending from the drop will, in virtue of their tension, tend to pull the surface outwards, thus diminishing the pressure within the drop, and so neutralising the effect of surface tension which produces a pressure.

If very small drops of water form a cloud, this will sink very slowly, owing to the viscous friction between the drops and the surrounding air. Sir George Stokes has shown that a cloud of water-drops, each of radius r, will sink with a velocity v given by the equation $v = (2gr^2)/9\mu$ where g is the acceleration due to gravity, and μ is the coefficient of viscosity of air.

We are now in a position to understand the method used by Prof. J. J. Thomson. When the volume of some air is suddenly increased the temperature of the air falls; hence if the air was originally saturated, it will be supersaturated after expansion, and if nuclei are present condensation will occur. The mass of aqueous vapour condensed can be calculated if the original volume and temperature of the air, together with the ratio of expansion, are known. By observing the velocity with which the resulting cloud descends, the radius and therefore the mass of each drop can be found; hence, knowing the mass of all the drops, and also the mass of each one, the number of drops can be calculated; and assuming that each drop is formed round an electron as nucleus, the number of electrons becomes known.

The apparatus used is represented diagrammatically in Fig. 7. A vessel A contains dust-free air saturated with aqueous vapour above water. This vessel is connected with a tube B containing an inner tube C which can move up or down freely. The inside of C is cut off from B by a water seal, while it communicates with the vessel E by means of the tube D. On suddenly diminishing the pressure within E the tube C is pulled downwards, thus increasing the volume of the air in A and B in a known ratio. The vessel F is partially exhausted, and on pulling down the rod H the inside of E is put into communication with F, the pressure in E falls, the tube C descends, and the expansion of the air in A causes condensation to occur. Electrons had previously been produced within A by means of X rays from a tube T in a metallic vessel; these rays pass through a thin sheet of aluminium Al connected to earth. When the ratio of expansion is only about 1·3, the electrons, and not the positively charged particles within A, act as condensation nuclei; the rate of descent of the resulting cloud is then observed, and from this the number of electrons in A is calculated. When the cloud has descended to the water, the charge communicated to the latter is deduced from the deflection of an electrometer connected to the water. Hence the number of electrons, and the sum of all their charges, is found, and the charge of each electron can be calculated. Proceeding in this manner, Professor J. J. Thomson found the value of the charge carried by a single electron to be equal to $3{\cdot}4 \times 10^{-10}$ electrostatic units. The estimated charge carried by a hydrogen atom in electrolysis is equal to $3{\cdot}1 \times 10^{-10}$ electrostatic units, so that, within the limits of experimental error, *the charge of an electron is equal to that carried by a hydrogen atom in electrolysis.*

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THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C., Chemical Engineer and Consulting Chemist, Manchester.

Measuring Instruments and their Technical Equivalents.

AMONGST the most important operations carried on in the laboratory are those relating to measurements. They are of manifold kinds, and are applied for the determination of the weights of solids, the volumes of liquids and gases, the temperature, the pressure in relation to that of the ordinary atmosphere, etc. The quantities to be dealt with in works, and the conditions under which operations are there conducted, are different from those which obtain in the laboratory; therefore it is evident that, although the principles upon which apparatus is constructed for use in large installations are substantially identical with those used in the construction of laboratory apparatus, yet the details and dimensions will be different.

Taking, as an instance, the balances used in the laboratory, we find that these depend upon the use of an oscillating beam, the position of the centre of gravity of which determines the sensibility of the instrument. In practical work, ordinary beam balances are frequently used in sizes which render it possible to determine weights up to one ton and more: fitted with knife edge centres and bearings, they can be made extremely sensitive, and are therefore particularly useful in the handling of expensive goods. A more convenient arrangement is represented by a "platform" weighing machine, which may be either made on the principle of the foregoing balances or on the principle of decimal or centesimal leverage; such a machine is shown in Fig. 31, where a platform is connected by a system of levers with the indicating apparatus which carries the weights. The levers are adjusted in such a manner that the object placed on the platform can be balanced by 1/10th or 1/100th of its own weight. The indicating arrangement consists of a steelyard graduated in pounds and fractions of a pound, and at its extreme point carrying an arrangement for supporting weights representing cwts. and fractions of a cwt. The lbs. and fractions of a lb. are determined by a device similar to the rider on a chemical balance, *i.e.*, by a running weight which moves on the divisions on the steelyard. These weighing machines can be made to carry weights up to eight, ten, and more tons. Some of the smaller machines are constructed in such a manner that they require no weights, but indicate the result on a dial; others may be made to weigh definite quantities of powdery substances automatically by a system of shutters acted on by levers.

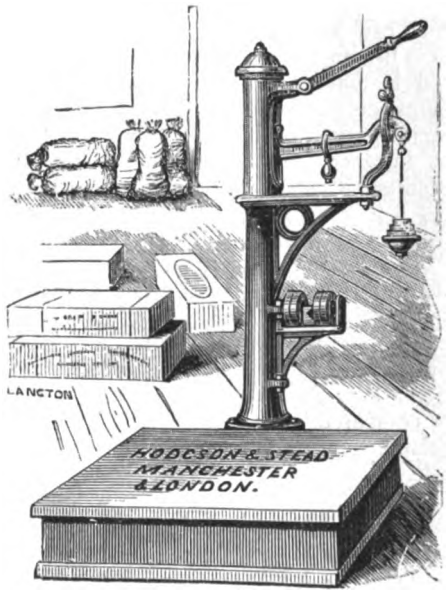

FIG. 31.—PLATFORM WEIGHING MACHINE.

The measurement of liquids, where equal quantities are often used, is generally performed in vessels of convenient shape, preferably rectangular. The contents of these vessels may be found either by calculation, or by filling them with water to the required level and ascertaining the volume by calculation from the weight obtained. As one cubic foot of water weighs 62·35 lbs., and has a volume of 6·235 gallons, it is easy to calculate from the weight in lbs. how many cubic feet or how many gallons a vessel will hold. In like manner, when it is desirable to ascertain the volume of a liquid other than water, this can be easily ascertained by weighing the liquid, and dividing the weight in lbs. thus obtained by the specific gravity of the liquid

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multiplied by 6·235; the result will then give the capacity in gallons.

In the laboratory, the determination of the specific gravity of a liquid by the aid of a "pyknometer" is somewhat tedious; in a works, the "areometer" is used for the same purpose, and enables one to obtain the result almost instantly. This appliance consists of a bulbous body and a thin stem; the former is filled with shot or mercury, and its total weight is adjusted so that when it is dipped into a liquid it will sink to a depth depending on specific gravity of the liquid. The stem is divided so that the scale marked on it indicates the specific gravity of a liquid at the point to which the stem sinks into it; the stem may be graduated with figures giving the specific gravity direct, or in some scale which can be easily converted into this. In Great Britain, the areometer which is generally used is that named after Twaddell; each degree corresponds to an addition in the specific gravity of water of 0·005, so that if, for instance, the instrument indicates 6° Twaddell, it means that the specific gravity is $(1 + 6 \times 0{\cdot}005) = 1{\cdot}03$. If the instrument indicates 53° Twaddell, the specific gravity is $(1 + 53 \times 0{\cdot}005) = 1{\cdot}265$. On the continent there are several other areometers used; Table I. will enable measurements in any of these arbitrary scales to be converted approximately into specific gravities, or *vice versâ*; *d* is the specific gravity of a liquid (as compared with water = 1), and *n* is the variable showing the degree in any particular scale.

Before leaving the subject of weights and measures, it may be useful to point out that there are certain coincidences which enable us to convert English weights and measures into their metric equivalents without tedious calculations, the results being sufficiently accurate for ordinary work. Thus, for instance, an English ton contains 2,240 lbs.; and as 1 kilo. is equal to 2·2 lbs., for purposes of quick calculations it may be taken that 1,000 kilos. are equal to 1 ton, or that 50 kilos are equal to 1 cwt. As 1 cubic foot of water weighs 997·6 ozs. (which is very nearly 1,000 ozs.), and as one litre weighs 1,000 grams, it follows that densities expressed in grams per litre also represent similar results expressed in ozs. per cubic foot. Thus, for instance, if an analysis gives us 55·5 grams of salt per litre, we can say straight away that this represents 55·5 ozs. (or 3·47 lbs.) of salt per cubic foot. Again, 1 gallon is equal to 10 lbs.; therefore grams per litre divided by 100 give lbs. per gallon.

TABLE I.—TO CONVERT VARIOUS SCALES INTO SPECIFIC GRAVITY, OR *vice versâ*.

For liquids heavier than water.

Baumé	d . .	=	$\frac{145{\cdot}9}{145{\cdot}9 - n}$.
Cartier	d . .	=	$\frac{136{\cdot}8}{126{\cdot}1 - n}$.
Beck	d . .	=	$\frac{170}{170 - n}$.
Brix	d . .	=	$\frac{400}{400 - n}$.
Balling	d . .	=	$\frac{200}{200 - n}$.
Gay-Lussac	d . .	=	$\frac{100}{100 - n}$.
Twaddell	d . .	=	$\frac{\frac{n}{2} + 100}{100}$.

For liquids lighter than water.

Baumé	d . .	=	$\frac{145{\cdot}9}{135{\cdot}9 + n}$.
Cartier	d . .	=	$\frac{136{\cdot}8}{126{\cdot}1 + n}$.
Beck	d . .	=	$\frac{170}{170 + n}$.
Brix	d . .	=	$\frac{400}{400 + n}$.
Balling	d . .	=	$\frac{200}{200 + n}$.
Gay-Lussac	d . .	=	$\frac{100}{100 + n}$.

Also, as 1 gallon is equal to 70,000 grains, results found in grams per litre, when multiplied by 70, will give the result in grains per gallon.

Where it is necessary to measure a quantity of gas in motion, a meter of a kind similar to that used for the measurement of coal gas is used. Where this is not practicable the speed with which the gases travel is determined. Suppose we want to determine the amount of sulphurous acid which passes into the atmosphere from a chimney. We can easily determine the amount of sulphurous acid per cubic foot by aspirating that volume, or a multiple of it, through a standard iodine solution. By ascertaining from drawings, or by measuring the sectional area of the chimney at the point at which we took the sample, we can find the number of cubic feet of gas which pass through the chimney in a certain time, if we know the speed at which the gases travel. The apparatus which

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is used for determining the speed is called an anemometer, and is based upon the movement of a column of ether in a tube when under the influence of a current of gas.

The measurement of temperatures in the laboratory is nearly always performed by means of an ordinary mercury thermometer, and the same instrument is used on a large scale where this is feasible. It must be borne in mind, however, that the ordinary thermometer is only trustworthy within limits which are not too near to the freezing or the boiling point of mercury. For temperatures higher than 320° C. or 330° C., it is now possible to use specially constructed mercury thermometers; the space above the mercury is filled with nitrogen or carbonic acid under pressure, and the bulb and tubes are made of refractory glass, so that temperatures up to 550° C. can be measured. A serious objection to glass thermometers is that they are liable to be broken. This objection can, to some extent, be overcome by encasing them in suitable metal cases, leaving uncovered that part of the scale on which the reading is to be observed. In order to meet different requirements, thermometers are constructed of all sizes and shapes up to three feet and more in length, bent at right angles or in other ways, and constructed in such a manner that the scale is only uncovered for that range of degrees which it is desirable to observe. For temperatures above 550° C. instruments are used which are termed "pyrometers." The construction of these is based on different principles; one class of construction depends upon the fact that metals expand with a rise of temperature, and the increase in length in the metal (which may be in the shape of a bar or a spiral) is transferred by a lever arrangement to a scale, and indicated by a pointer. Pyrometers have also been constructed which depend upon the principle of the expansion of air, the heat being indicated on a dial in a similar manner. It may be stated here, as a rule which applies to all instruments for temperature measurement, that it is necessary to check them from time to time; this applies not only to pyrometers, but also to thermometers, which, as is well known, change in the course of time.

One of the simplest and (if properly conducted) one of the most trustworthy ways of determining high temperatures is by means of the calorimeter. The calorimeter is based on the fact that if a substance of known specific heat and weight, heated to a certain temperature, is dropped into a known quantity of water of known temperature, it will cause this water to rise in temperature by a definite amount. If, therefore, the weight and the specific heat of the substance be known, and a definite quantity of water be taken for the purpose of the experiment, it will be possible, from the rise of temperature of the water, to determine the temperature to which the heated substance was raised. The apparatus consists of a metal vessel, generally made of sheet copper, which is placed in a wooden box, the space between the two being filled with a bad conductor, such as wool or similar substances. The copper vessel is covered with a lid which is provided with two holes—one to admit a thermometer graduated in tenths of degrees, and the other to permit the heated mass of metal to be introduced. A copper stirrer is provided, so that the water in the calorimeter can be mixed to equalise the temperature. The mass of metal to be heated may take the form of a cylinder made of wrought iron, copper, nickel, or platinum. In order to carry out the test, the apparatus is filled to two-thirds with an accurately measured quantity of water. The metal cylinder is placed in a metal spoon fixed on a sufficiently long rod, and passed into the flue or furnace, of which the temperature has to be determined: it is left there for a sufficient time (twenty minutes or half an hour), and then quickly removed and dropped into the calorimeter. The temperature of the water in the calorimeter is taken shortly before the metal cylinder is dropped into it, and immediately after. Let the original temperature of the water be t, while the maximum temperature after inserting the heated cylinder is t_1; let the weight of the metal cylinder be p, while the specific heat of the metal of which it is made is c; then, if the water equivalent of the copper vessel and its contents is p_1, the temperature T of the hot cylinder is

$$T = t_1 + \frac{p_1 (t_1 - t)}{pc}.$$

The water equivalent of the vessel and stirrer is the actual weight of these multiplied by the specific heat of copper. This is added to the mass of water in the calorimeter in order to obtain p_1. It must not be forgotten that the specific heat of metals varies with the temperature, and this fact should be taken into consideration.

A very convenient appliance for measuring temperatures is now at our disposal in the form of the electrical thermometer. This instrument may be either of the *resistance* or the *thermo-electric* type. In the resistance

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thermometers, use is made of the fact that the electrical resistance of a metal depends upon the temperature; so that if, for instance, a platinum wire is exposed to the heat of a furnace, the current produced in it by a given E.M.F. will vary with the temperature of the wire. The thermo-electric thermometer, on the other hand, depends upon the fact that if two wires of different metals (as, for instance, wires of iridium and platinum) are joined at their ends, an E.M.F. is produced which varies with the temperature to which the junction of the wires is exposed, and the resulting current can be measured by means of a galvanometer which may be adjusted in such a manner that degrees Centigrade or Fahrenheit are shown on its scale. These instruments are extremely useful, particularly as they can be used in situations where it would be difficult to introduce other kinds of thermometers; but it is important here, as in every other case, to check the instruments from time to time.

Another kind of thermometer which is now much used goes by the name of the "Thalpotassimeter." This instrument works on the principle that the vapour of a liquid confined in a closed space will possess a pressure, depending on the temperature of the liquid, which can be read off on a convenient scale. The liquids which may be used for the purpose vary according to the temperatures which are required to be measured. For low temperatures, such as required in a vacuum apparatus, etc., ether or alcohol may be used; for higher temperatures, mercury or other liquids are employed. A system of determining temperatures, often used in furnaces in the manufacture of pottery and similar wares, consists of little cones made of glazing material of different degrees of fusibility. The approximate melting point of these cones is known; and, by placing a number of them in the furnace, it can be easily ascertained which of them melt, and which remain unmelted.

For quick determinations which may be left to the workman, it is sometimes convenient to make use of the known temperatures at which certain metals or compounds melt. Thus, for instance, potassium nitrate melts at 329°, and bismuth at 264°. If we introduce these two substances (in a little spoon which is fixed on a long handle) into the furnace of which we want to test the temperature, and if we find that the bismuth melts, and that the potassium nitrate does not, then we may take it that the real temperature is between the 329° and 264° C.

(To be continued.)

THE OPTICAL CONVENTION OF 1905.

By JOHN P. LORD.

IF the Optical Convention of 1905, opened on the last day of May, suffices to impress on the scientific public the fact that all branches of optical manufacture are receiving due attention from firms in this country, it will have fulfilled its mission. Years ago there may have been some truth in the jibe that in England we cannot make optical instruments; to-day such a statement is utterly untrue. In certain laboratories and teaching establishments instruments of foreign make are still used; but such preference is simply the result of ignorance on the part of persons who have long been satisfied with the products of a few foreign firms, and have not troubled to enquire whether equally good or better instruments are not made by our own workmen. If the Optical Convention serves to draw the attention of the public to the present state of the optical industry in the United Kingdom, it will have done great good to the cause of science, and will have helped to remove one of the great stumbling blocks which have long stood in the way of our enterprising manufacturers. Given encouragement, our English workmen can produce articles in every way comparable with the best products of foreign workshops.

Taken as a whole, the Optical Convention may be said to be thoroughly representative of our best English opticians and of their work; here and there we miss exhibits by familiar firms, but the catalogue contains accounts of the latest developments in the branches of optical science for which these firms are famous, and, with remarkable generosity, no secrets have been withheld.

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It would be foolish if I pretended to any finality in my selections from the mass of exhibits. All cannot be mentioned; some must. I have simply selected and described the articles in each section which specially attracted my attention. At this point I wish to gratefully acknowledge the kindly courtesy of the exhibitors who have supplied me with details whenever requested, and of the organising staff of the Convention for their willingness to make the task before me as easy as possible.

No one will deny that the last twenty years has seen a wonderful advance in optics. This advance has progressed along two parallel lines; while the theorist, with paper and pencil, has made elaborate calculations and has freely given to the world the products of his brains, the practical manufacturer has spared no expense in keeping up with the progress effected in the study and laboratory. Design and calculation have been readily followed by improved methods of manufacture and by the use of superior materials.

In a short article like the present it is quite impossible to make mention of the theoretical advance in optics which has taken place in recent years. I propose, therefore, simply to mention the instruments which have formed the practical outcome of this advance.

First and foremost comes the glass of which the essential parts of so many instruments of precision are made. To the ordinary man, all specimens of glass are alike; to the optician, no two meltings are exactly similar. Abbe and Schott, subsidised by the Prussian Government, produced glasses which have practically revolutionised optics; one must not, however, jump to the conclusion that the superior glasses, known familiarly as Jena glasses, can only be obtained from Germany. Messrs. Chance Brothers and Co., Ltd., of Birmingham, now actually produce almost every variety of Jena glass required by opticians; and I am informed that in the near future every known species of glass will be made in England if only British opticians will patronise the industries of their own country. Quite recently Messrs. Chance have produced four new species of optical glass, one with a coefficient of dispersion as low as 0·00770, and another, a boro-silicate flint, with a coefficient of dispersion of 0·01187; the latter is the first boro-silicate flint, of equal quality, produced in England. Further, the boro-silicate crowns of this firm are quite remarkable for their transparency and freedom from colour.

The "turned" spheres of Messrs. James Powell and Sons, and the sets of lenses of Aitchison and Co., both of London, are also worthy of examination by all interested in this branch of optics.

Those who like to "see how a thing is made" will be interested in the exhibit of Messrs. George Culver, Ltd., of White Lion-street, N. The chief interest in this exhibit lies in the fact that hitherto it has been commonly stated that no optician in England can work cylindrical lenses, and accordingly the trade has obtained its cylindrical lenses from abroad. Messrs. Culver show the tools

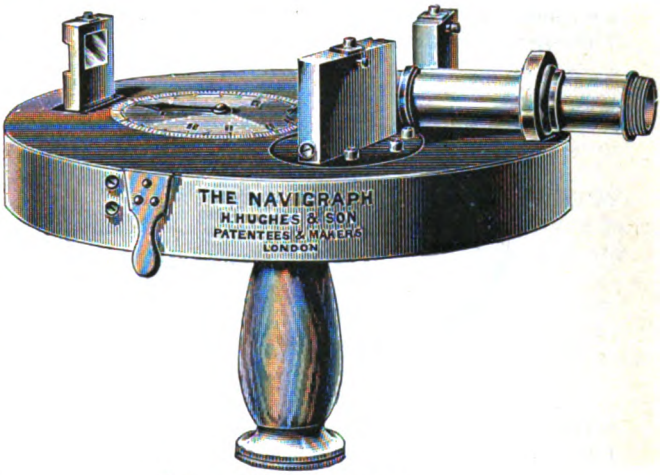

FIG. 1.—THE NAVIGRAPH.

with which they grind cylindrical lenses of any desired radius, and photographs of their works prove that in London cylindrical lenses are made daily.

The quartz fibres shown by the Cambridge Scientific Instrument Co., and manufactured after the method devised by Mr. C. V. Boys, F.R.S., are of great interest. The quartz is fused, and then a drop is drawn out by means of a light arrow fired from a cross-bow.

With regard to prisms, the exhibits of R. and J. Beck, of Cornhill, and A. Hilger, of Camden-road, are interesting, showing, as they do, wonderful accuracy of workmanship and great appreciation of the peculiar qualities of the glasses employed. From these we turn to Lord Blythwood's exhibit of diffraction gratings, ruled on speculum metal, with 14,400 lines to the inch. The spectra obtained by their use are beauti-

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fully clear and wonderfully free from foreign colour.

Few can afford to purchase first-class telescopes—in fact, the sale for good telescopes is so limited that one wonders how it is that our English opticians can afford to make such magnificent instruments. The section devoted to this branch of optics is unfortunately very incomplete, for naturally manufacturers do not keep a stock of first-class instruments on hand. Some beautiful astronomical instruments have been made by several of our leading firms, and are mentioned in the catalogue; but as some of these are at Cape Town and others at the observatory of the Government of India at Kodaikanal, Madura, India, they are not available to the ordinary public. Of the Indian instruments I can speak with authority, for I know the Kodaikanal Observatory well. The new instruments there have been supplied by the Cambridge Scientific Instrument Company, Limited, and are examples of perfect workmanship. Their spectroheliograph, which is an instrument designed for obtaining photographs of the curious protuberances on the sun, using monochromatic light of any desired wave length, is a masterpiece of design and construction. This branch of solar physics is comparatively new, and requires instruments of the highest perfection. I believe that the observatory under the Rev. Fr. Frankelin, successor to Fr. De Peneranda, at St. Xavier's College, Calcutta, is the only other Indian observatory equipped with a spectroheliograph.

The exhibits of Sir Howard Grubb, of Rathmines, Dublin, are admirable, and quite maintain the reputation which this veteran firm of opticians has acquired. Passing over the more pretentious instruments, I shall only mention a portable equatorial telescope with a 5-inch aperture, and weighing only 77 lbs., which has just been constructed. This is a most handy instrument, and one which the amateur observer will find admirable and inexpensive. Most ingenious is the electric commutator which accelerates or retards the clock, and so gives a great range of freedom in the slow motion in R.A. This instrument has many of its parts constructed out of "magnalium," which gives rigidity without weight: the entire design marks an advance in the right direction. Practical astronomers will greatly appreciate its many devices which conduce to accuracy and comfort.

I may also mention an equatorial with a 3-inch object glass, made by Messrs. Watson, of Holborn. It is a thoroughly practical instrument with all the necessary motions, operated by Hooke's handles, and with clamps, and so forth. Those who desire a useful equatorial at a moderate price will find that this instrument will meet their needs.

I cannot say whether the "navigraph," designed and made by Messrs. Hughes, of Fenchurch Street, is a novelty or not; certainly I have never seen one before, though I have some experience of instruments used in navigation. It is extremely ingenious and should prove of great use to the skippers of coasting steamers, and of especial value to those who have to take ships round the Indian and Persian shores. By its use the position of the vessel is marked on the chart, and the "off shore danger angle," that safeguard of the modern mariner, can be determined and security ensured.

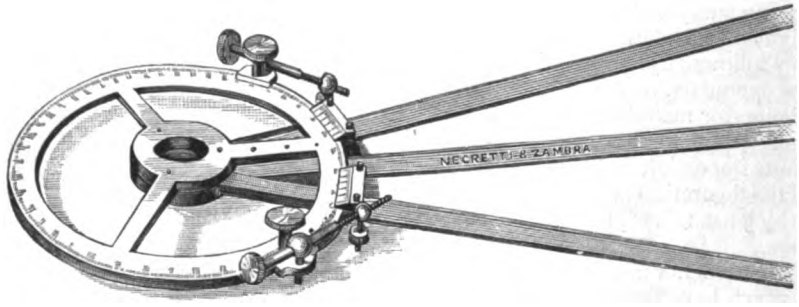

FIG. 2.—THE STATION POINTER.

While speaking of this phase of navigation I cannot forbear from mentioning the new station pointer made by Messrs. Negretti and Zambra. The "station pointer" is an instrument long known to the surveyor and occasionally found in the chart room of vessels, but it is not yet fully appreciated. By its use any observed angles can be laid down, and the position of a ship, or of the observer, determined on the chart in an instant. Hitherto the station pointer has been made of heavy brass, and

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in practice it has often been found that the brass obscured the most important features on the chart, thus greatly diminishing the value of the instrument. Messrs. Negretti and Zambra make the circle of this instrument of transparent celluloid, so that the only objection to its use is removed. The new form is perfectly stable, does not warp in high temperatures, and is most convenient to use. This improvement should do much to popularise this very handy tool, and I feel sure that if its worth were fully appreciated it would rank next to the sextant in every chart room.

Of sextants, of course, there is no lack; but Messrs. Hicks, of Hatton Garden, have shown me one which has a unique record. After exhaustive tests at Kew it is certified that on no point is there any error. Its record is a long list of "o"s.

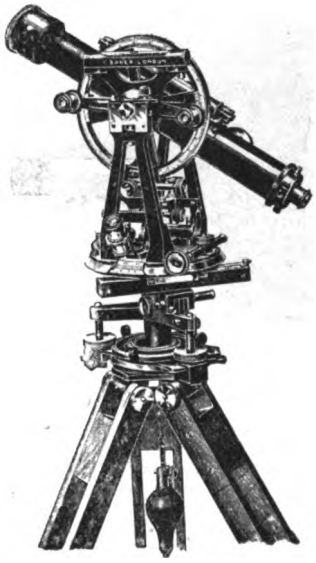

FIG. 3.—THE TACHEOMETER.

The transition from navigation instruments to those used by the surveyor is a natural one, and in this connection theodolites must be mentioned. Baker's tacheometer, or telemetrical theodolite, is certainly a beautiful instrument. It embraces every known movement; can measure any visible angle; is absolutely steady; is strong; and, considering its perfections, is inexpensive. Who that has used a theodolite does not know the annoying parallax which obscures the best observations and keeps one dodging one's head about behind the instrument, trying to get a fairly fixed "sight." This minor trouble is entirely eliminated in the tacheometer devised by Mr. Charles Baker, of High Holborn. The stadia lines are no longer composed of webs or engraved on a disc of glass inserted in the eye-piece; they are accurately engraved on the field lens of a Kellner eye-piece, and so the lines are clear, easily cleaned, and parallax is avoided. The eye lens has a focussing adjustment, showing up the stadia lines clearly. The telescope is an anallatic one and defines beautifully. The field is large and clear. The stadia lines are of constant value—a great advantage in practice.

The instrument transits from the object glass end, making the unlocking of the V's unnecessary except in very special cases. Surveyors will do well to look at this perfected form of the theodolite. One very minor point—who, that has used a theodolite, has not accidentally pulled out one of the reading microscopes on a cold morning, and found it very hard to replace? Provision is made in this tacheometer against this natural weakness. The microscopes, which magnify the clearly cut scales, cannot be drawn out of their tubes entirely, and so there is no fear of any accident happening.

With regard to general surveying instruments, those interested will find the exhibits of Messrs. Stanley and Co., Ltd., well worth attention. The standard of excellence which this firm has long maintained is well demonstrated in their exhibits. They are showing a very fine high-power tacheometrical theodolite, and also a solar attachment for theodolites, both of which are interesting and of value to surveyors.

Among levels, Stanley's patent quick setting-up level is easily distinguishable. It is practical and speedy, and in these days of hustle, that means much. Not long ago, I saw one being used by a surveyor who was levelling on very uneven ground. He had a partner with him who was using the usual form, and it was the rapidity with which the user of the Stanley instrument got this into position that first drew my attention to it. The ball joint on which the level is mounted gives all the advantages of the Hoffmann head, and all the freedom of the three-screw mounting; with the tribrach system of mounting on which the ball is carried there is no position which cannot be attained. There is no continental instrument which can compare with this level.

Among mining instruments one stands out clearly in my mind as I write. This is an unpretentious, simple sort of tool, and at first glance would not seem to compare with the beautiful specimens of brass and magnalium

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which the miner's dials present; but it is practical, and, after all, that is the great point. I refer to the Brunton-Pearse pocket mine transit, made by Messrs. Negretti and Zambra. It is the result of the combined experience of two well-known experts, and is simple and very portable, weighing under 10 ozs. The needle is steady, and the mirror arrangement fitted enables one to take the necessary sights and read the compass at the same time. Personally I should be inclined to think that this instrument, which is an alt-azimuth as well as a clinometer, should soon replace the obsolete prismatic compass of the army officer. It is better, lighter, cheaper, and much more efficient.

The same firm exhibits the best box sextant that I have ever handled. Anyone who has used a box sextant will tell you that there is always a feeling of insecurity while holding the instrument with the left hand and moving the sector by means of the milled head with the right hand. In Negretti's box sextant the screw is placed nearer the edge than in the instruments of other makers, and it works so freely that both hands can be used to maintain the level of the instrument, while the milled head is moved by the second finger. The difference in comfort and in rapidity of working is enormous: all shake is gone, with its consequent strain on the eyes, and the readings are clear and can be made with accuracy.

FIG. 5.—THE BOX SEXTANT.

For pocket surveying instruments, none approaches in ingenuity those of Messrs. Hicks, of Hatton Garden. The famous "Grubb levels" are really wonderful: a whole outfit can be carried in a coat-pocket, and the work will be good at the end of the day. Very noteworthy is the little pocket surveying instrument, which is quite the clearest instrument to read that I have ever seen. It is about as large as a tobacco pipe, and of much the same shape, but it reads vertical and horizontal angles to degrees with unfailing accuracy, and it is not at all trying to the eyes to use. Of course, these are only for rough-and-ready surveys and for military work; but they are a distinct acquisition to British optics and are well worth looking at. All the instruments which I have seen, made by this firm, are sound, beautifully finished, and accurate.

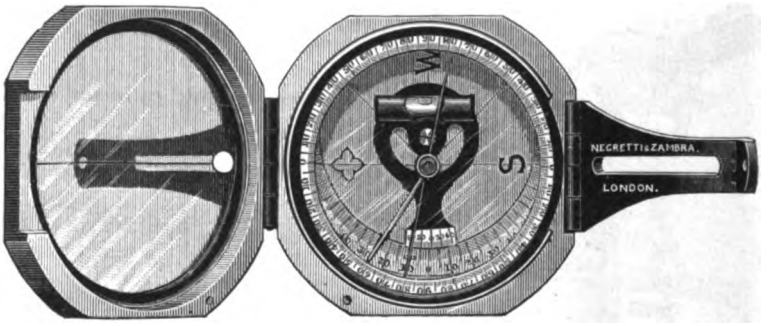

FIG. 4.—THE BRUNTON-PEARSE MINE TRANSIT.

From surveying let us turn to meteorology. Here again we have the firm of Hicks in the foreground. They have several very wonderful aneroids on show—pocket instruments with the accuracy of standard barometers. Also they have a marvellous machine that is called a "meteorograph." This is a light board which may be attached to a kite, and supports a circular card and one or two aluminium pens. One pen is attached to a simple human hair: this gives a record of the humidity of the air; another gives the temperature, and a third is operated by a very light aneroid, which records the barometric pressure at the aerial station. A clock records the time of each observation.

For thermometers I shall not be accused of partiality if I again mention Negretti and Zambra. Their standard thermometers, of course, are on show, but these are in use in almost every English laboratory and observing station. Their latest deep sea thermometer,

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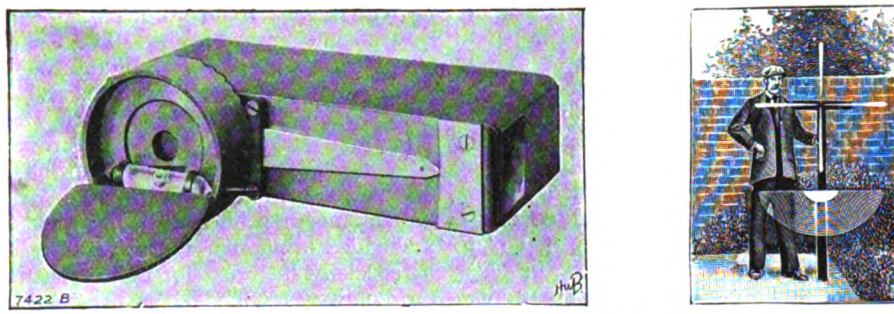

FIG. 6.—THE "GRUBB" POCKET LEVEL, SHOWING APPEARANCE OF FIELD SEEN BY OBSERVER.

however, demands special mention. It is so constructed that when it reaches the bottom of the sea it takes its record: the instant the observer begins to haul it up it is reversed, and thenceforth indicates the temperature at which it stood when it was reversed. A standard Fortin barometer, with an enlarged scale, made by the same firm, is also remarkable and representative of British industry.

In microscope manufacture England stands first, in spite of the efforts of pathologists to magnify foreign instruments. You can buy a good lens abroad, everyone admits that, but for the best stand and condenser you must come to England.

It is difficult to describe the exhibits in the microscopical section, because there is so much that is excellent that one might be accused of invidiousness; but I will simply speak of those articles which have especially attracted my attention.

With the exception of a semi-apochromatic objective of one-twelfth of an inch focus, oil immersion, the celebrated firm of Powell and Lealand is not exhibiting much. The lens shown, however, is remarkable as having a numerical aperture of 1·40, and costs less than any foreign lens, of equal quality, with a numerical aperture of 1·30. In fact, at the price it is the finest lens on the market; no optician will deny that.

Messrs. Watson are showing some splendid instruments. First of all there is the "Van Heurck," the instrument that the famous Belgian scientist had made for him as the *ne plus ultra* of microscope stands. To-day, with this model before them, all continental opticians have to admit that they cannot approach our English stands in accuracy, convenience, and beauty of workmanship. And this is only one of the first-class stands which are at once the admiration and the despair of foreign microscope makers.

Messrs. Baker, of Holborn, make an equally good stand, which they mention in the catalogue but are not showing — their Nelson microscope. This is a first-class stand in every sense of the word, but I think I prefer the R.M.S. model which they are actually exhibiting. It is light but stable, is fitted with every modern improvement, including a fine adjustment to the sub-stage, and is a thoroughly practical instrument.

Messrs. Watson have a series of their

FIG. 7.—POCKET SURVEYING INSTRUMENT.

famous "Edinburgh student's models" and one of their "Royals." All these are splendid instruments, quite unapproached by any continental firm. Indeed, it is a wonder to me why teachers of bacteriology in our hospitals should adhere to indifferent instruments by continental makers, in preference to first-class microscopes made by English firms—prejudice, and prejudice alone, can account for this blind obstruction of scientific progress.

Excellent models are shown by Messrs. R. and J. Beck, of Cornhill. They have long made useful instruments, but they seem to have a predilection for the continental stand, and though they do make several tripod instruments, I am assured that they still find a readier sale for the old horseshoe foot. Ross's instruments are practical, but again the foreign foot is to the fore. Messrs. Swift, of Tottenham Court Road, make an excellent series, and would have shown them, but for the fact that large Government orders cleared their stock out just before the Convention opened.

Coming to cheaper instruments, everybody

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knows the "Star," made by Messrs. Beck, and everybody should know the "Fram" and the "Argus," made by Watson. The "Fram" is the finest cheap microscope made by any firm, and on the continent it would be sold at nearly double its London price: all the accessories which go to make up a thoroughly excellent instrument can be added to it. Close on its heels follows the "Discovery" by Swift, and the various patterns of "The London" by Beck. Mr. Baker's "D.P.H." is a higher grade of instrument: both patterns as they stand are suitable for serious work, and require no additions.

The advance of bacteriology and the necessity for blood examination has made a portable microscope a necessity to physicians; the very best pattern that has yet been produced is shown by Mr. Charles Baker. It was originally exhibited at the Quekett Club, and was there eulogised by the President, a man of great experience. It is absolutely rigid, being the first light microscope for which this can be claimed. It is fitted with a perfect sub-stage with arrangements for centring and focussing, and has a mechanical stage which is simple but efficient. Its movements for focussing are smooth and very durable; above all, it packs up into a space sufficiently small to enable an army doctor to carry it on his cross-belt.

As to objectives, I should like to mention the holoscopic series made by Messrs. Watson. They are nominally achromatic, but in reality should be classed as semi-apochromatic. Their colour correction is so good, and the flatness of field so marked, that after comparing them with the very best semi-apochromatics by the leading foreign firms, I am bound to extol them. This is exceptionally gratifying to us, especially as these lenses have been designed by one of our countrymen, as well as made by English workmen. Messrs. Baker make one or two exceptional lenses which should stand by themselves, the most notable, perhaps, being their 1/8 with an n.a. of 0·94, and their oil immersion 1/12, with an n.a. of 1·30. Both of these compare favourably with any foreign lens of equal angle.

With regard to accessories to the microscope there is little really new. Messrs. Beck are showing a very useful optical bench, which enables one to arrange the microscope for monochromatic light with great precision; and both Messrs. Baker and Watson exhibit benches for photo-micrography which are thoroughly practical, and quite equal, if not superior, to anything made on the continent.

With regard to microtomes, several good instruments are exhibited. The Cambridge Rocking Microtome, made by the Cambridge Scientific Instrument Company, is well known. Messrs. R. and J. Beck exhibit the Delépine Microtome, made according to instructions of Professor Delépine, who has used the instrument in his laboratory for several years. This microtome may be used for cutting tissues imbedded in paraffin wax or in celloidin, and is specially intended for cutting sections of frozen tissues, imbedded or not imbedded in celloidin. It is characterised by extreme rigidity, both of the razor and of the object cut; by the simplicity and delicacy of the mechanism for raising the object holder; and by the rapidity with which large numbers of sections can be cut. It can be provided with a special ether box and a CO_2 freezing chamber for maintaining frozen sections at a low temperature. The section is only raised after the knife has been withdrawn.

Last comes photography. Amongst photographers there are as many opinions as there are men, and so I will only venture to point out one or two articles which strike me as being of exceptional interest. Messrs. Dallmeyer make a very excellent telephotographic lens, which is moderate in price, and gives the amateur who wishes to take up this very delightful branch of photography a chance of doing good work. The "Adon" lens, made by the same firm, is well worthy of mention. The homocentric lenses, made by Messrs. Ross, are also remarkable: each consists of

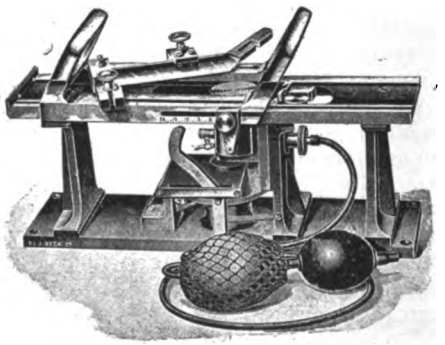

FIG. 8.—DELÉPINE MICROTOME.

four single meniscus lenses, and has ample space for shutters. The point that strikes one most about them is their power of covering the plate sharply right up to the extreme edge. The "holostigmat-convertible" of Messrs. Watson is a lens which all who are interested in this branch of optics should see.

Of instruments, cameras, and so forth,

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there is no end; and I should not be acting wisely if I mentioned any of them. All are good specimens of British handicraft; but, after all, that branch belongs more to the cabinet-maker than to the optician, and so I may be excused if I do not deal with them here.

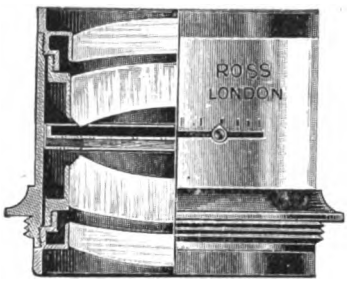

FIG. 9.—HOMOCENTRIC LENS.

To one who is interested in the progress of British manufactures, the Optical Convention of 1905 is peculiarly important. It is a vindication of the fact that when proper time is given the British manufacturer can show workmanship equal to any produced on the Continent. No one understanding the difficulties in the way of the British optician could attend this Convention without feeling proud that his countrymen have produced a show which would do credit to any State-subsidised body of scientists, and without feeling that whatever may be the cheap jibes cast at Britain, her sons can produce, and daily do produce, scientific instruments which will bear comparison with the best our competitors can show us.

REVIEWS.

A Treatise on the Analytical Dynamics of Particles and Rigid Bodies; with an Introduction to the Problem of Three Bodies. By E. T. Whittaker, M.A., Fellow and Lecturer of Trinity College, Cambridge. pp. xiv. + 414. (Cambridge: University Press; and London: C. J. Clay & Sons, 1904). Price 12*s.* 6*d.* net.

In writing this book the author has aimed at setting forth, as completely as limitations of space would permit, the analytical theory of the motion of those dynamical systems which possess a finite number of degrees of freedom. In the early chapters the treatment of the subject is of a fairly elementary character—elementary, that is, to one possessing a competent knowledge of the Higher Mathematics and a good general acquaintance with the principles of Dynamics. The reader who conscientiously follows up the development of the subject, as presented by the author, is brought into close touch with those views of theoretical Dynamics which have become prominent in recent years. It has been customary, in the past, to divide Dynamics into two sections—the Dynamics of a Particle, and the Dynamics of a Rigid Body; and these branches have generally been discussed in separate volumes. There is, however, considerable advantage to the reader in the method adopted by Mr. Whittaker, who treats of both these branches in a single volume, and shows the mutual interdependence between them. Preference is shown for general methods of solution as distinguished from those special artifices which are useful only for small groups of problems.

A large proportion of the subject-matter of this book has hitherto been accessible only in scattered memoirs by various investigators, among whom may be mentioned Lie, Rayleigh, Klein, Hertz, Lorentz, Poincaré, Siacci, Bruns, Boltzmann, Larmor, Greenhill, Appell, Painlevé, Stäkel, and Levi-Civita; in giving a connected account of these investigations, the author has achieved a most difficult and yet useful task in an admirable manner, and those who are competent to follow him in his treatment of the subject cannot but feel deeply grateful. The following is the order in which the subject is developed in successive chapters:—Kinematical Preliminaries; The Equations of Motion; Principles Available for Integrations; Soluble Problems of the Dynamics of a Particle; Dynamical Specification of Bodies; Soluble Problems in Rigid Dynamics; Theory of Vibrations; Non-Holonomic Systems and Dissipative Systems; The Principles of Hamilton and Gauss; Hamilton Systems and their Integral-Invariants; Transformation Theory of Dynamics; Properties of Integrals of Dynamical Systems; Reduction of the Problem of Three Bodies; Theorems of Bruns and Poincaré; General Theory of Orbits; Integration by Trigonometric Series. The principles explained in each chapter are illustrated by worked problems, and numerous problems to be solved by the reader are appended.

Electro-Magnetic Theory of Light. By C. E. Curry, Ph.D. Part I. pp. xvi + 400. (London: Macmillan and Co., 1905). Price 12*s.* net.

Maxwell's Electro-Magnetic Theory of Light lends itself admirably to a development illustrating modern methods of mathematical analysis; indeed, the temptation of an author writing on this subject is to lose sight, to a great extent, of the physical basis of the theory, and to needlessly surround the subject with clouds of

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symbols expressing the solution of differential equations. It is with regret that we have to confess that Dr. Curry has, in great measure, succumbed to temptation "I have," the author remarks in his preface, "omitted a description of all experiments on the subject-matter treated, and have referred to empirical facts only where a comparison with the theoretical results has seemed of interest." Has seemed of interest! The value of Maxwell's theory is that it explains the most diverse physical phenomena in a connected manner; but the author of the book before us finds most interest in mathematical analysis, and so the physical phenomena are allowed to take care of themselves. Thus, on page 2, in discussing the corpuscular theory of light, we are told that "particles [*i.e.*, the supposed light corpuscles] travelling at such high velocities would impart an enormous momentum to the object on which they strike, and thus set it in motion; but observations have failed to detect any such motion, even when the supposed particles are brought to a focus on the given object by means of a lens or mirror." We have failed to find any mention of the fact that, according to Maxwell's theory, light exerts a definite pressure on objects on which it falls; and a reference in a footnote, "See, however, P. Lebedew: Untersuchungen ueber die Drückkrafte des Lichts, Drudi's Annalen 6, 1901, Vol. II., pp. 433-458," would hardly lead the reader to conclude that the pressure of light has been experimentally observed by Lebedew, and that Nichols and Hull, in a beautiful series of experiments, have found that this pressure agrees, within very narrow limits, with the value predicted from theory. Further, we have been able to trace no mention of the result obtained by Poynting and Heaviside, relating to the transmission of energy by electro-magnetic waves; of Lord Rayleigh's investigations concerning the scattering of light by small particles; of theories explaining dispersion and its connection with the absorption of a medium; and a reference to X-rays on p. 63 would lead the reader to suppose that these consist of waves in which the "oscillations do not, in general, take place at right angles to their direction of propagation," while the accepted view is that X-rays consist of radiations differing from light chiefly in the fact that their wave-length is much smaller. Finally, no index has been added—a great defect in a volume which is intended to serve as a work of reference.

Elementary Steam Engineering. By H. W. Metcalfe, Engineer Commander, Royal Navy. pp. xiv. + 208, with 144 diagrams. (London: Longmans, Green and Co., 1905.) Price 7*s.* 6*d.* net.

This book has been written for students in the position of the greater number of the cadets at Osborne, who, at the commencement of their studies, know scarcely anything about the fundamental principles of physics and mechanics, and whose powers of observing and recording their observations must be developed before an ordinary text-book can be read with advantage. For this purpose a better book than that before us could scarcely be imagined; the principles of kinematics and mechanics are illustrated from details of engines, and the student is taught to make drawings on squared paper—a most valuable acquisition. One can easily imagine the popularity of such a course of instruction if it were taken up at our public schools.

The Telegraphists' Guide to the Department and City and Guilds Examination in Telegraphy. By James Bell, A.I.E.E., and S. Wilson, A.M.I.E.E. Fifth edition (new impression). pp. xii. + 227. (London: S. Rentell and Co., Ltd., 1905.) Price 2*s.*

This work has been written with the object of preparing students for the requirements of the technical examination imposed on telegraphists aspiring to superior appointments in the Government telegraph service.

Jute and Linen Weaving. Part I.: Mechanism. **By Thomas Woodhouse,** Dundee Technical Institute, and **Thomas Milne,** Dunfermline Technical School. pp. xvi. + 383. With 221 illustrations. (Manchester: Emmott and Co., Ltd.; and London: 118, Chancery Lane. 1904.) Price 10*s.* net, post free.

This is certainly the most comprehensive work yet published on the mechanism used in jute and linen weaving. While it will prove of the greatest value to those engaged in the jute and linen trades, yet many portions will be of interest to all engaged in the textile industry. Every endeavour has been made to render the book as complete as possible. The writing is clear and concise, and the illustrations are in every respect admirable. This book should appeal not only to students, but also to practical men, who will find therein how much technical advantage can be derived from a systematic study of the theoretical side of their occupation.

Introductory Mathematics. By R. B. Morgan, B.Litt., L.C.P. pp. vi. + 151, with 113 diagrams. (London: Blackie and Son, 1905.) Price 2*s.*

This little volume deals with those elementary portions of algebra, geometry, and graphs which a boy ought to know before he can be said to have done more than obtain an introduction to mathematics.

The Motor Manual. Compiled and Illustrated by the Staff of "The Motor." Seventh Edition. pp. 115, with 109 diagrams. (London: Temple Press, Ltd., 1905.) Price 1*s.* net.

This is a useful book, dealing in a popular but clear and helpful manner with the construction, principles of working, and management of steam and petrol engines and electric motors, such as are used for cycles and cars. It contains a useful section devoted to repairs, a glossary of technical terms, and useful tables.

Painters' Oils, Colours, and Varnishes. Edited by Paul N. Hasluck. pp. 160, with 51 diagrams. (London: Cassell and Co., Ltd., 1905.) Price 2*s.*

This is a book compiled from articles and general information previously published in the *Building World*. Considering its size, it contains a great amount of useful information, and it will doubtless be of service to those engaged in the oil and colour trade.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

SODIUM BISULPHITE.—What is the action of sodium bisulphite on naphthylamine sulphonic acids?

The reaction mentioned by our correspondent is a particular case of the application of an important property of bisulphites. It has recently been shown by Bucherer (*Journal für Praktische Chemie*, 1904, [ii], 69, 49, and *Zeitschrift für Farben-und Textil-Industrie*, 1904, 3, 57) that compounds which contain an amino-group directly attached to an aromatic (benzenoid) nucleus are altered when warmed with solutions of bisulphites, and when the products are hydrolysed by mineral acids, sulphur dioxide is evolved and the amino-group of the original compound is found to have been replaced by a hydroxyl group.

The reaction probably proceeds in the following stages :—

$$R\cdot NH_2 + 2\,Na\,HSO_3 = NH_3 + Na_2SO_3 + R\cdot O\cdot SO\cdot OH$$

$$R\cdot O\cdot SO\cdot OH + H_2O = R\cdot OH + H_2SO_3\ [= H_2O + SO_2]$$

The intermediate compounds thus appear to be the sulphurous acid esters of the phenols, and it is interesting to note that the foregoing reactions appear to be reversible, for when phenols are heated with ammonia and sulphurous acid (ammonium sulphite) the corresponding amino-compounds are obtained. The changes here may perhaps be expressed as follows :—

$$R\cdot OH + 2\,(NH_4)\,HSO_3 = R\cdot O\cdot SO\cdot OH + (NH_4)_2SO_3$$

$$R\cdot O\cdot SO\cdot OH + 2\,NH_3 = R\cdot NH_2 + (NH_4)\,HSO_3.$$

FULMINATES.—Discuss the constitution of fulminic acid and the fulminates?

The fulminates are derived from an acid having the same empirical formula as cyanic acid, HOCN; the acid is scarcely known in the free state, but resembles hydrocyanic acid in its odour, and, like that substance, is exceedingly poisonous.

By the action of strong hydrochloric acid upon the salts of fulminates, an addition product appears to be produced in the first instance, so that salts of a new acid having the formula HCl NOH are produced. This acid may be obtained in well-formed crystals, is closely related to the fulminates as they may be regenerated from the new acid by the action of bases in aqueous solution, but is converted by warm hydrochloric acid into formic acid and hydroxylamine hydrochloride.

$$HCl\,NOH + 2H_2O = HCO_2H + NH_2OH\cdot HCl.$$

The last-mentioned reaction immediately suggests that the chlorine containing acid has the constitution of an oxime, and if so it must contain the group $:C = N\cdot OH$, which leaves for the chloro-acid the only likely formula $\begin{matrix}H\\Cl\end{matrix}\!\!>\!C = N\cdot OH$, which represents it as the oxime of formyl chloride $\begin{matrix}H\\Cl\end{matrix}\!\!>\!C = O$, a suggestion apparently confirmed by its action on aniline, which results in the production of phenylisouretin.

$$HC(NO)\cdot Cl + NH_2\cdot Ph = H\,Cl + HC(NOH)\cdot NH\cdot Ph.$$

Since, then, the fulminates appear so closely related to formylchloride oxime, and afford it by the addition of hydrogen chloride, the simplest view which may be taken as to the constitution of fulminic acid is evidently $C:N\cdot OH$, in which a carbon atom is assumed to be divalent—the substance is, in fact, assumed to be the oxime of carbon monoxide. (Compare the answer on carbon monoxide given in the last number)

On this assumption the conversion of a fulminate into formylchloride oxime may be represented as follows :—

$$C:N\cdot O\cdot Ag + H\,Cl = \begin{matrix}H\\Cl\end{matrix}\!\!>\!C:N\cdot O\cdot Ag$$

$$\begin{matrix}H\\Cl\end{matrix}\!\!>\!C:N\cdot O\cdot Ag + H\,Cl$$

$$= \begin{matrix}H\\Cl\end{matrix}\!\!>\!C:N\cdot O\cdot H + Ag\,Cl.$$

STEREOCHEMISTRY.—Give an account of the stereochemistry of compounds of nitrogen, sulphur, tin, and silicon and lead (if anything is known about it).

Compounds of tervalent nitrogen are not known in enantiomorphous forms, but certain cases of isomerism, suspected to be due to peculiarities of the tervalent nitrogen atom, have been detected. Such cases are very rare where the nitrogen atom is singly bound to three different atoms or groups, and are here possibly capable of an interpretation not involving any supposed peculiarity of the nitrogen atom.

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Cases of isomerism are frequent where a nitrogen atom is attached by two of its "bonds" to another atom or group, a condition we may represent as $X \gtrless N - Y$, and includes those compounds (*a*) in which the tervalent atom forms part of a closed chain, and (*b*) in which the atom is doubly bound to one other atom.

Isomerism, which may be referred to type (*a*), appears to exist in the following instances. Coniine (isomeric with *iso*coniine), stilbazoline and *iso*stilbazoline, tropine and ψ-tropine. In the last instance, both compounds are inactive, and it seems very clear that the isomerism is an effect due to the tervalent nitrogen atom; the formula of tropine is

$$\begin{array}{l} CH_2-CH-\!\!-CH_2 \\ \quad\;\; |\qquad\;\; | \\ \quad\;\; N\cdot CH_3\, CH\cdot ON \\ \quad\;\; |\qquad\;\; | \\ CH_2-CH-\!\!-CH_2 \end{array}$$

Types of isomerism which belong to class (*b*) are found among the ketoximes, the hydrazones and diazo-compounds. Oximes of the type $NOH:C\lessgtr^{a}_{a}$ are found in one form only, but oximes obtained from nonsymmetrical ketones are often found in two. Hantsch and Werner assume that in these cases the third nitrogen "bond" does not lie in the same plane as the other two, and represent the isomers by means of the formulæ

$$\begin{array}{ll} a\cdot C\cdot b & a\cdot C\cdot b \\ \quad\| \quad \text{and} & \quad\| \\ HO\cdot N & \quad N\cdot OH \end{array}$$

an hypothesis which can at once be extended to hydrazones. The isomerism of the diazo-compounds (*not* diazonium salts) may be explained in a similar manner, and the "*syn*" and "*anti*" diazocyanides, for example, are usually formulated thus:—

$$\begin{array}{ll} Ph\cdot N & Ph\cdot N \\ \quad\| \quad \text{and} & \quad\| \\ CN\cdot N & \quad N\cdot CN \end{array}$$

In compounds of quinquivalent nitrogen, isomerism is not known in the type N *a a a b* X. In the type N *a a b c* X cases of very unstable isomerism, perhaps due merely to dimorphism in the crystalline state, have been detected, but in general only one form can be detected when no asymmetric carbon atom is present. Definite results are obtained only when the nitrogen is wholly "asymmetric," a condition represented by the formula N*abcd*X. Wedekind obtained two inactive modifications of phenyl-benzyl-allyl-methyl-ammonium iodide, and one of these Pope and Peachey succeeded in resolving into two enantiomorphous forms by the aid of silver bromocamphorsulphonate, which afforded two salts *d*-base-*d*-acid and *l*-base-*d*-acid from which, by the action of potassium iodide, the enantiomorphous active iodides were subsequently obtained, and these have equal but opposite effects on the plane of polarisation of light. Other similar cases have since been investigated, partly with positive and partly with negative results. It is yet too early to state definitely what configuration may be assigned to the compounds of quinquivalent nitrogen, but the results hitherto obtained suggest a "pyramidal" or "double tetrahedron" form as the most probable.

Sulphur.—Attempts to obtain direct evidence as to the configuration of sulphur compounds previous to the year 1900 give ambiguous results; Pope and Peachey, however, succeeding finally in obtaining an optically active substance which owed its properties to the presence of a sulphur atom attached to four different groups; this substance was a *d* methylethylthetine platinichloride

$$2\,\begin{matrix} C_2H_5 \\ Cl \end{matrix}\!\!>\!S\!<\!\begin{matrix} CH_2\cdot CO_2H \\ CH_3 \end{matrix}, PtCl_4$$

and was obtained by subjecting to careful fractional crystallisation methylethylthetine *d*-camphorsulphonate and then, from the most sparingly soluble part, preparing the platinichloride of the contained base. In the same year, Smiles obtained an optically active methyl-ethylphenacyl-sulphine picrate

$$\begin{matrix} CH_3 \\ C_2H_5 \end{matrix}\!\!>\!S\!<\!\begin{matrix} CH_2\cdot CO\cdot C_6H_5 \\ O\cdot C_6H_2(NO_2)_3 \end{matrix}$$

by a similar process. These observations prove conclusively that the four groups attached to a quadrivalent sulphur atom do not lie in one plane.

Tin.—Pope and Peachey prepared methyl-ethyl-*n*-propyl tin iodide $\begin{matrix} CH_3 \\ C_2H_5 \end{matrix}\!\!>\!S\!<\!\begin{matrix} C_3H_7 \\ I \end{matrix}$ and in 1900 announced that they had succeeded in obtaining from it *d*-methyl-ethyl-*n*-propyl tin *d*-camphorsulphonate, and from an aqueous solution of this, an addition of potassium iodide, *d*-methyl-ethyl-*n*-propyl tin iodide separated as a faintly yellow oil which was sometimes optically active and sometimes inactive, a behaviour attributed by the authors to racemisation; some months later they found that the *d*-camphor-sulphonate itself underwent racemisation in aqueous solution. The existence of optically active compounds of quadrivalent tin shows that these compounds have a space configuration of the tetrahedral type long recognised in carbon compounds and since established in the cases of quadrivalent sulphur and tellurium compounds.

No definite experimental evidence on the question of the space relationship of silicon or lead compounds has as yet been obtained.

RADII OF GYRATION.—If two systems of mass lying in a plane have the same centre of mass and the same radii of gyration about three different lines in the plane, prove that they have the same radii of gyration about every line. Hence prove that when calculating the radius of gyration of a triangular area (or uniform plate), we may replace the triangle by three equal particles at the middle points of the side.—*London B.Sc.*, 1904.

The radius of gyration of any system of masses about any given line being known, the radius of

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gyration about a parallel axis through the mass centre can be calculated when the distance d between the M.C. and the line is known; in symbols

$$k^2 = k^2 + d^2.$$

Hence the radii of gyration for all parallel axes can be calculated.

In Fig. 1, O is the M.C., P is any point in the plane having a mass m concentrated there, Ox and Oy are $\perp^r$ axes about which the spin-radii are k_1 and k_2, while x and y are coordinates of P with reference to Ox and Oy. If OM be any line through O making an angle θ with Ox, the moment of inertia of m about OM is $m\mathrm{PM}^2$, and thence the moment of inertia of the whole system of masses about OM is

$$\begin{aligned} I &= \Sigma m\mathrm{PM}^2 \\ &= \Sigma m(y\cos\theta - x\sin\theta) \\ &= \Sigma m(x^2\sin^2\theta + y^2\cos^2\theta - 2xy\sin\theta.\cos\theta). \end{aligned}$$

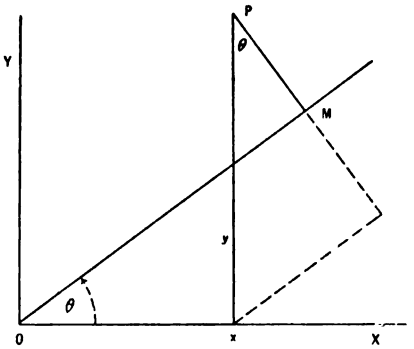

FIG. 1.—RADII OF GYRATION.

If k denote spin-radius about OM, and M is the total mass,

$$\mathrm{M}k^2 = \sin^2\theta.\mathrm{M}k_2^2 + \cos^2\theta.\mathrm{M}k_1^2 - 2\cos\theta\sin\theta.\Sigma mxy,$$

or

$$k^2 = k_2^2\sin^2\theta + k_1^2\cos^2\theta - 2\cos\theta\sin\theta\,\frac{\Sigma mxy}{\mathrm{M}}.$$

Evidently if the system of masses has an axis of right symmetry, and this be taken as the axis of y, then

$$\Sigma mxy = 0, \text{ and } k^2 = k_2^2\sin^2\theta + k_1^2\cos^2\theta.$$

In any case, k^2 can be calculated when θ is known.

Now set off along OM a length OQ = r (say), so that $rk = c^2$, where c is any convenient length, and do this for a number of different positions of OM; the locus of Q will be a curve whose equation is

$$\begin{aligned} c^4 &= r^2\sin^2\theta\cdot k_2^2 + r^2\cos^2\theta\cdot k_1^2 - 2r^2\cos\theta\sin\theta\,\frac{\Sigma mxy}{\mathrm{M}} \\ &= x^2k_1^2 + y^2k_2^2 - 2xy\,\frac{\Sigma mxy}{\mathrm{M}}. \end{aligned}$$

This represents an ellipse, for r is always finite.

If the ellipse be supposed drawn, then the k about any line may be found by measuring r, the radius vector, and using the formula

$$k = \frac{c^2}{r}.$$

Obviously, if we had chosen our axes as axes of the ellipse, the equation would have assumed the simple form

$$c^4 = x^2k_1^2 + y^2k_2^2.$$

If we know the k's for three lines through the M.C., and set off the three corresponding points Q by aid of the equation $r = \frac{c^2}{k}$, we have three points on the ellipse, and its centre. But three points and the centre completely determine an ellipse, the curve can be constructed, and the k for any line found.

Given, then, that two systems of masses have the same k's for three lines, they must have (if c be chosen the same in both cases) the same ellipse, called the momental ellipse, and therefore their k's must be the same for all axes.

The k^2 for a triangular area about a line through its vertex parallel to the base is easily proved to be $\frac{1}{2}p^2$ where p is the altitude of the triangle. Again, for three equal masses at the mid-points of the sides, k^2 about the same line is given by

$$3mk^2 = mp^2 + m\frac{p^2}{4} + m\frac{p^2}{4},$$

or

$$k^2 = \frac{p^2}{2}.$$

Hence for the three lines through the vertices of the triangle parallel respectively to the opposite sides, the spin radii for the triangle and for the three equal mass particles at the mid-points of the sides are the same. By the preceding investigation, then, the momental ellipse must be the same for the two systems, and hence the spin-radii must be the same for all axes.

GEOMETRY OF THREE DIMENSIONS.—A solid is bounded by any surfaces, plane or curved. Two figures built up of prisms are now constructed such that one figure *includes* and the other is *included by* the given solid. Prove that these figures have a common limiting value when the number of prisms is infinitely great, and further, that the value is unique.

One essential point is omitted in this enunciation, *viz.*, that at least one point on each end face of each prism is a point on the surface of the given solid. The proviso that the prisms must fit one another, so that no space is left between them, is perhaps too obvious to mention. Otherwise, there is nothing to limit the length of the prisms in the first case, or their shortness in the second case. To render the argument clearer, suppose the prisms, in the including figure, have all the same cross-sectional area A, then if $l_1, l_2, l_3 \ldots$ be the lengths of the prisms, the volume may be represented by $\Sigma\mathrm{A}l = \mathrm{A}\Sigma l$.

Let $h_1, h_2 \ldots$ be the greatest lengths of the edges of the prisms projecting outside the given solid, at one end of the prisms, and $k_1, k_2 \ldots$ the corresponding maximum lengths projecting at the other ends. Then the volume of the prisms outside the given solid is clearly less than $\Sigma\mathrm{A}(h + k)$, *i.e.*, $< \mathrm{A}\Sigma(h + k)$.

Hence, volume of solid $< \mathrm{A}\Sigma l$.

$$> \mathrm{A}\{\Sigma l - \Sigma(h + k)\}.$$

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As the number of prisms increases, A diminishes and Σl increases, the product $A\Sigma l$ remaining finite, while each h and k gets less and less.

In the ratio $\frac{\Sigma(h+k)}{\Sigma l}$ we know that its value lies somewhere between the greatest and least value of $\frac{h+k}{l}$ (proved in any algebra), but when the number of prisms is infinitely large, l is finite and $h + k$ vanishes.

Hence, in the limit $\frac{\Sigma(h+k)}{\Sigma l}$ vanishes, and the volume of the solid lies somewhere between the limiting value of $A\Sigma l$ and the limiting value of $A\Sigma l\left\{1 - \frac{\Sigma(h+k)}{\Sigma l}\right\}$.

But we have just seen that these have the same limiting value, and the volume of the solid is therefore limiting value of $A\Sigma l$.

For the included prism figure, if B denote the common cross-section of the prisms, $m_1, m_2 \ldots$ their lengths, $i_1, i_2 \ldots j_1, j_2 \ldots$ the maximum lengths of prisms between the ends and the given solids' surface, then

Volume of given solid $> B\Sigma m$

$< B\{\Sigma m + \Sigma(i + j)\}$.

We can easily show, as before, that when the number of prisms becomes infinitely large, both these expressions have the same value, *viz.*, the volume of the solid.

Hence, both the including and included prism volumes have a common limiting value which is the volume of the solid. The common limiting value is therefore unique, and independent of the particular shaped prisms originally chosen.

FLUID PRESSURE.—The particles of a given mass of homogeneous liquid at rest attract each other according to the law of nature: find the pressure at any point. (It is the treatment of the infinite number of centres that is the puzzle).—*Besant's Hydromechanics, Ex. II.*, 3.

The fundamental pressure equation in hydrostatics is

$$dp = \rho\,(X\,dx + Y\,dy + Z\,dz)$$

where ρ is the density and X, Y, Z are the components, parallel to the axes, of the forces per unit mass acting at x, y, z.

The force per unit mass at P (x, y, z), due to a mass dm at A (α, β, γ) is

$$G\frac{dm}{r^2}$$

where G is the constant of gravitation and r is the distance between the points A and P, the force having the sense from P to A.

The component of this force $\parallel$ to the axis of x is

$$G\,dm\,\frac{(\alpha - x)}{r^3}$$

Hence, taking account of all the attracting masses,

$$X = G\,\Sigma\frac{dm\,(\alpha - x)}{r^3}\,dx,\quad Y = G\,\Sigma\frac{dm\,(\beta - y)}{r^3}\,dy$$

$$Z = G\,\Sigma\frac{dm\,(\gamma - z)}{r^3}\,dz.$$

But $r^2 = (\alpha - x)^2 + (\beta - y)^2 + (\gamma - z)^2$.

Hence

$$r\,dr = -\{(\alpha - x)\,dx + (\beta - y)\,dy + (\gamma - z)\,dz\}$$

and $dp = -G\rho\,\Sigma\frac{dm\,.\,dr}{r^2}$.

The fluid being homogeneous, the mass per unit volume at any point is independent of r, and therefore

$$p = -G\rho\,\Sigma\,dm\int\frac{dr}{r^2} + C$$

$$= G\rho\,\Sigma\frac{dm}{r} + C;$$

The constant C being determined when we know the pressure at the free surface.

$\Sigma\frac{dm}{r}$ is the potential at P due to all the surrounding fluid.

Since the fluid is at rest, we may from considerations of symmetry assume the mass to be spherical in form. Required, then, the value of

$$\int\frac{dm}{r}$$

for a given point within a spherical mass.

Let O be the centre of the sphere, c the distance of P from O, R the distance of A from O; then, since all the mass on the circle of intersection of sphere of radius R and plane through A $\perp^r$ to c is at the same distance from P, we may take

$\Sigma\,dm$ for the circle $= \rho\,2\pi\,R\sin\theta\,d\,R\,.\,R\,d\theta$;

and $r^2 = c^2 + R^2 - 2cR\cos\theta$.

Hence

$$\int\frac{dm}{r} = 2\pi\rho\int_0^{\infty}\int_0^{\pi}\frac{R^2\sin\theta\,d\theta\,dR}{\sqrt{c^2 + R^2 - 2cR\cos\theta}}$$

where a is the radius of the sphere.

Integrating first with regard to θ, we notice that $2cR\sin\theta\,d\theta = d(c^2 + R^2 - 2cR\cos\theta)$.

And hence,

$$\int\frac{dm}{r} = 2\pi\rho\int_0^a\frac{R}{C}\left[\sqrt{c^2 + R^2 - 2cR\cos\theta}\right]_0^{\pi}dR.$$

In taking the limits we must be careful to

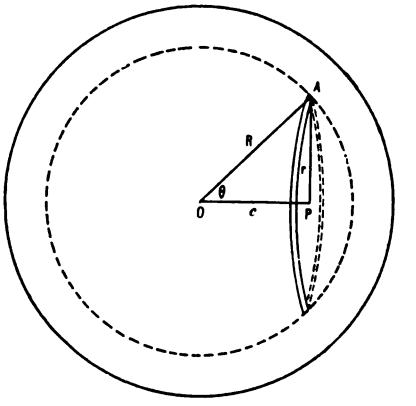

FIG. 1.—FLUID PRESSURE.

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take the square root correctly. For $\theta = \pi$ we have $\sqrt{c^2 + R^2 + 2cR}$ . . $= C + R$; but for $\theta = o$ $\sqrt{C^2 + R^2 - 2cR}$ may be either $C - R$ or $R - C$, according as $C >$ or $< R$. Hence, we must take the second integration in two parts—one from O to c, and one from c to a, and

$$\int \frac{dm}{r} = 2\pi\rho \int_0^c \frac{R}{c}(c + R - \overline{c - R})\, dR.$$
$$+ 2\pi\rho \int_c^a \frac{R}{c}(c + R - \overline{R - c})\, dR.$$
$$= 2\pi\rho \left\{\frac{2}{3}\frac{R^3}{c} + (a^2 - c^2)\right\}$$
$$= 2\pi\rho\,(a^2 - \frac{1}{3}c^2).$$

Returning to the pressure equation, we have

$$p = 2\pi G\rho^2 (a^2 - \frac{1}{3}c^2) + C.$$

If the free surface is one of zero pressure,

$$o = \frac{4}{3}\pi G\rho^2 a^2 + c$$

and $$p = \frac{2}{3}\pi G\rho^2 (a^2 - c^2).$$

As regards the infinite number of centres, it is true they exist; but to find the pressure at any *one* point, all we require is the force per unit mass acting there, and we have only to consider that one point as the centre of forces. The force-pressure equation, which was the starting-point, gives the relation between the pressure and the forces acting at any point; it only depends on other forces inasmuch as they help to determine the pressure.

VIBRATION.—Determine the stress in the neck of the crankshaft of a high-speed engine, due to gyrostatic action, when (owing to excessive vibration) the plane of rotation of the flywheel is displaced through a given angle. The problem has arisen in the course of practical work. Owing to a badly equipped test house, I am frequently obliged to test large high-speed electric lighting engines (up to 900 E.H.P.) on a small testing bed, which is quite unsuited for the work. The engines have usually to be run before the arrival of the generators. Owing to the small testing bed, the vibration is very severe, and causes the plane of rotation of the flywheel to oscillate very considerably. I have frequently (in bad cases) shut an engine down, fearing an accident, and not being able to calculate the stress produced in the neck of the crankshaft.

If the plane of rotation of a flywheel be displaced about any axis, the stress produced in the shaft by gyrostatic action may be calculated as follows. Let

I = moment of inertia of wheel about its axis of rotation, *viz.*, the shaft.

ω_1 = angular velocity of wheel about the above axis, *i.e.*, $\frac{2\pi \times \text{R.P.M.}}{60}$

ω = angular velocity of displacement of plane of rotation.

Then the gyrostatic action produces a twisting moment of magnitude $I\omega_1\omega$ about the diameter of the wheel, acting in a plane perpendicular to those in which ω_1 and ω are measured (*vide* TECHNICS, September, 1904, p. 227).

Where the plane of rotation has a periodic motion, as in the case of movement through an angle θ on either side of its mean position by reason of engine vibrations, the actual motion may be somewhat complicated; but for all practical purposes it may be regarded as a simple harmonic movement. The greatest value of ω is then given by

$$\omega = 2\pi n\theta$$

where n is the number of complete to-and-fro oscillations per second.

Substituting the values of ω and ω_1, the maximum twisting moment is then

$$(2\pi)^2 N I n\theta$$

where N = revolutions per second made by wheel.

This moment applied to the crankshaft at the wheel boss is opposed by an equal and opposite one at the nearest section of the shaft prevented from bending, *i.e.*, a short distance within the brass of the bearing next the wheel boss. The length of shaft between these two points is then under a pure bending stress of moment $4\pi^2 N I n\theta$.

For a circular shaft of radius r, the maximum stress f is given by equating f to $\frac{4}{\pi r^3} \times$ (bending moment), or in this instance

$$f = \frac{16\pi N I n\theta}{r^3}.$$

As an illustration of the above relations, the wheel represented in Fig. 1 may be considered, the revolutions being 300 per minute, and the oscillations taken as synchronous with them, so that $n = 5$. Then

I of web
$$= \frac{\text{Weight in pounds}}{32} \cdot \frac{R_1^2}{2} = \frac{200}{32} \cdot \frac{\cdot 84}{2} = 2\cdot 63.$$

I of rim
$$= \frac{\text{Weight in pounds}}{32} \cdot \frac{R_2^2 + R_1^2}{2} = \frac{592}{32} \cdot \frac{2\cdot 4}{2} = 22\cdot 8$$

I. of entire wheel $= 2\cdot 63 + 22\cdot 8 = 25\cdot 43$ pound-feet.
$= 305$ pound-inches.

$$\theta = \frac{\cdot 875 - \cdot 125}{30} = 0\cdot 025.$$

T.M. = B.M. $= 4\pi^2 \times 5 \times 305 \times 5 \times \cdot 025 = 7550$,

and if the diameter of shaft be taken as 3 inches,

$$f = \frac{4 \times 7550}{\pi 1\cdot 5^3} = 2840.$$

Now it is in the highest degree improbable that the lateral oscillation of the wheel would exceed its vertical motion with a vibrating vertical engine; and the force required to produce the translatory acceleration, in general, produces a far greater stress than any gyrostatic action.

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Assuming the wheel to oscillate up and down with a throw of $\frac{3}{4}$ of an inch above and below the mean position, the accelerating force at the extreme positions is given by

$$\frac{\text{Weight in pounds}}{32} \cdot (2\pi n)^2 \times \text{throw};$$

in this case

$$\frac{792}{32} \cdot (10\pi)^2 \cdot \frac{75}{12} = 1530 \text{ pounds},$$

and if the distance from the centre of the width of wheel to the point of support in the bearing brass be taken as small as 5 inches (in the writer's experience, the point of support is regarded for purposes of calculation as one-third the length of bearing in from the end), the bending moment becomes $1530 \times 5 = 7650$

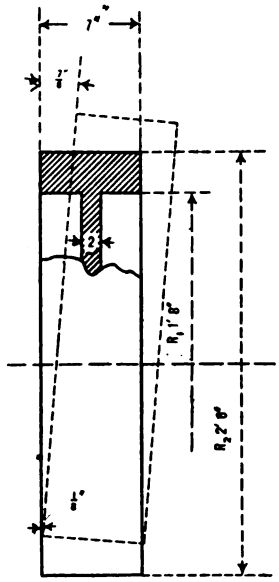

FIG. 1.—VIBRATION.

pound-inches, or, in all, with the moment due to the dead weight of the wheel, 11,600 pound-inches.

Comparing, then, the 7550 due to the gyrostatic action with the 7650 due to the reciprocating motion, and having regard to the fact that, with a vertical engine, almost all the former stress will be exerted horizontally from front to back of the engine or *vice versâ*, and is thus straining chiefly that part of the shaft's metal which is least strained otherwise, it is evident that the gyrostatic stress may usually be omitted from consideration.

In calculating the stress due to the oscillating motion, it should be noted that n is not necessarily equal to the number of engine revolutions made per second; indeed, with double line engines, it is rather likely to be twice as great, but a general rule cannot be laid down.

CEMENT.—Gypsum is added to Portland cement after burning to regulate setting time. State method for quantitative determination of gypsum so added.

There is a general consensus of expert opinion that 2 per cent. of gypsum is the utmost quantity which may be added to pure Portland cement, for the purpose of retarding the setting action, without injurious influence upon its ultimate strength; though one or two authorities advocate the adoption of 3 per cent. as a maximum. Without doubt, 5 per cent. causes unmistakable signs of disintegration. Within the narrow limits thus determined, the exact amount to be added will depend upon the chemical constitution and the physical condition of the cement. It can only be arrived at experimentally, and will vary with individual cases. Thus, in two instances, the period of setting "hard" was protracted to 24 hours, from 5 minutes and 4 hours respectively, by the addition of 2 per cent. of gypsum. In another case, $\frac{1}{2}$ per cent. of gypsum retarded the setting action by 7 hours. In yet another instance, 1 per cent. of gypsum produced an equal retardation. As a matter of fact, it is difficult to assign values to the influence of several agencies which are at work. Sluggishness in setting may be due to an excess of lime, while fineness of grinding undoubtedly quickens the setting action. Needless to say, an overlimed cement is bound to prove unsound. On the other hand, fineness of grinding is one of the most desirable features of a cement.

Efficient æration renders a cement slow-setting, by partially hydrating the aluminate of lime and so modifying its activity. Also, it has been pointed out by Signor Cantalupi that slowness of setting is promoted by the presence of alkalies, and the carbonates of soda and potash have been incorporated with cement, in small quantities, for this purpose. Bicarbonate of soda produces a very material retardation.

ANALYSIS OF LUBRICATING OILS.—Will you please inform me as to the best short methods of analysing lubricating oils; the methods given in the text-books are too intricate and require too much time.

Under the title of "lubricating oils" many different fatty and mineral oils are included. Originally, fatty oils were used exclusively for this purpose; but with the tremendous increase in production and improvements in treatment of mineral oils, the latter have to a large extent replaced the fatty oils. The former are still, however, used to a considerable extent, especially when intimately mixed with mineral oils. Mineral oils and fatty oils usually mix in all proportions: the one exception is castor oil, which requires special preliminary treatment before it can be incorporated with mineral oil.

In analysing lubricating oils we have therefore to make ourselves acquainted not only with the analysis of mineral oils, but fatty oils, waxes, etc. One of the first tests which can be usefully applied to a lubricating oil has for its object the determination of the proportions in which

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the mineral and vegetable or fatty oils are mixed together (if the oil in question be a mixture), or to detect the presence of vegetable and mineral oils in lubricating oils. The simplest test we can apply depends upon the striking difference in chemical constitution in these two classes of bodies.

Mineral oils are hydro carbons, and therefore unaffected by treatment with alkali. Vegetable or animal oils are "esters," and are saponified on treatment with an alkali. Hence the application of an alkali, if the required conditions be observed, will have the effect of removing the fatty oil as a soap, leaving the mineral oil unchanged. A lubricating oil can be tested roughly on these lines by shaking a few cc. with strong solution of caustic potash. The fatty oils at once begin to saponify, and this materially aids the formation of an emulsion; thus a fatty oil almost immediately emulsifies under these conditions, whereas a mineral oil remains almost unchanged, or only yields a very slight emulsion, often little more than mere cloudiness.

If the oil under examination be a mixture of a fatty and a mineral oil, the larger the proportion of the former the more apparent is the formation of an emulsion. But even with practice this is only a very rough-and-ready method, and in order to estimate more accurately the proportions of fatty and mineral oils in the mixture, a more careful quantitative experiment should be carried out. For this purpose a carefully weighed quantity (10 to 20 grms.) of oil is taken, and treated with 30 to 40 cc. of alcohol or purified methylated spirits. About 5 grms. of solid caustic potash, dissolved in 20 cc. of water, is then added to the mixture, and the whole boiled under an inverted condenser for an hour or so. In this way the whole of the vegetable oil will be saponified while the mineral oil is left unchanged. The mineral oil can then be extracted from the aqueous liquor in a separating funnel by means of petroleum ether. The layer of petroleum ether which contains the mineral oil is removed, the ether evaporated, and the remaining oil weighed. Should the whole of the oil be saponified by this treatment, it will evidently contain no mineral oil. Instead of boiling in an inverted condenser, the reaction can be carried on in an open dish, but a much smaller proportion of alcohol must be used.

A discrimination between the various mineral oils is accomplished with extreme difficulty, and there are no simple analytical methods. The best indication of its nature is to be found in the physical qualities, such as colour, smell, fluorescence, etc. As to the fatty oils (this term includes vegetable and animal oils), those mostly in use for lubricating purposes are neat's foot oil, lard oil, tallow oil, rape oil, olive oil, and castor oil. These, as explained, are saponified on treatment with caustic potash. For distinguishing them in the mixture there are few simple methods. Reliance can only be placed on carefully conducted quantitative experiments. Most of the rough qualitative tests are unsatisfactory, but of these the following may be of some service.

The following tests depend upon the action of strong sulphuric acid on oils.

Having first decided whether the lubricating oil in question is a mineral or fatty oil, or a mixture of both, it may be treated with a small quantity of strong sulphuric acid in a white porcelain basin, and the colour produced noted. Pure mineral oils, if properly refined, give little or no colour, even when a mixture of the two is shaken together at the ordinary temperature, and at 100°C. there should only be the very slightest colour produced.

On the other hand, strong sulphuric acid reacts with the fatty oils at the ordinary temperature, producing various tints from yellow to brown.

The oils which are suitable for lubricating purposes do not, however, give this reaction so strongly as some of the other vegetable oils (such as linseed or cotton seed oils), which are quite unsuited for use as lubricating oils. These latter oils give darker clots with strong sulphuric acid. Certain blubber oils and liver oils, which are also unsuitable for lubricating purposes, give blue and purple colorations.

Another simple test depending on the action of sulphuric acid is the Maumene test, where the oil is mixed with a definite proportion of concentrated sulphuric acid, and the rise in temperature produced by the reaction measured with the thermometer. In making this test it is necessary always to adhere to the same conditions, especially with regard to the strength of sulphuric acid. A parallel test should always be made with a pure sample of the oil, the rise of temperature is taken with a thermometer, and the mixture of liquids stirred the whole time.

A test is most accurately performed, according to Archbutt, by placing 50 grms. of oil in a beaker with a capacity of about 200 cc. A thermometer is inserted and the temperature noted, which should preferably be as near as possible 20°C. 10 cc. of strong sulphuric acid are then added, the liquid being continuously stirred, and the highest point to which the temperature rises is noted. Mineral oils produce only a very small rise, probably not exceeding 10° or 20°, while the class of drying oils most unsuitable for lubricating oils will cause a rise sometimes approaching 120°.

The fatty oils, such as those already enumerated, suitable for lubricating, produce moderate rises in temperature. This test, then, gives a rough idea as to the type of oil with which we are working, and a very considerable rise of temperature would raise our suspicions. The colour of the mixed acid and oil may also be noted. A test easily and frequently applied to oils is the so-called "cold test," which is really a determination of the solidifying point of a lubricating oil. It is of importance, as on no account must an oil be used which would solidify in the tubes conveying the oil to the bearings of the machine. In this test the oil is placed in a test tube into which a thermometer is inserted:

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the test tube is then placed in a freezing mixture of some sort and constantly stirred with the thermometer. The temperature is allowed to sink much below that observed when the solid first appears. The test tube and its contents are then removed from the freezing mixture and kept stirred, and the temperature at which the last particle of solid melts is noted. The test tube is then again placed in the freezing mixture and the process repeated until the temperature found is constant. This temperature is taken as the setting point. The test tube should, if possible, be of a rather large size ($1\frac{1}{4}$ inch diameter), and should be filled to the depth of about 2 inches with the oil. A lubricating oil containing much paraffin would be rejected if treated in this manner, as the setting point would be low. It is, however, necessary in some cases to apply further tests for the purpose of more accurately measuring the amount of paraffin wax contained in the lubricating oil.

The method devised by Holde is shortly as follows :—

10 to 20 cc. of the oil are taken if it is poor, but 5 cc. are sufficient if it is rich in paraffin wax. This is placed in a flask of 150 to 200 cc. capacity, and sufficient of a mixture of equal parts of ether and absolute alcohol added to obtain a clear solution. It is then immersed in a freezing mixture at a temperature of about $-20°$C., and vigorously agitated, sufficient of a further quantity of the alcohol-ether mixture being added to cause the drops of oil to disappear, leaving only crystals or flocks of paraffin wax. The paraffin wax is filtered off on a cooled filter paper, and washed with the mixture of alcohol and ether, which must also have been previously cooled to $-20°$C. The washing is continued sufficiently long to remove all the oil. The paraffin wax is then rinsed, by means of benzene, from the filter into a small, tared dish, and on evaporating off the benzene the residual wax is weighed.

HYDRAULICS.—Water is admitted by a contracting mouthpiece from the bottom of tank into 4-inch pipe 600 feet long, and then allowed to escape vertically as a fountain through a 2-inch nozzle into the air, the nozzle being 100 feet below level of surface in tank. Find height above nozzle to which water will rise if the coefficient of resistance of pipe = ·005.—*Victoria University, B.Sc.*, 1896.

From the statement that a converging mouthpiece is fitted to the pipe at the point where it enters the tank, we may conclude that no energy is lost by a sudden change of velocity; and, therefore, that if the level of issue from the tank is the same as that of issue from the nozzle, the total initial head of the water is 100 ft., or that each lb. of water entering the pipe has 100 ft.-lbs. of energy, partly in the form of pressure energy, and partly in the form of kinetic energy. Hence,

$$\frac{P_A}{W} + \frac{V_A^2}{2g} = 100$$

when P denotes water pressure in lbs. per square foot, V velocity in feet per second, W the weight of a cub. ft. of water in lbs. (*viz.*, 62·5), and the suffix A the point considered, which we may take as that point, practically adjoining the tank, where the converging mouthpiece joins the 4-inch pipe.

At the nozzle this amount of energy is diminished owing to friction in passing along the pipe, and for a pipe of circular section,

$$h = \frac{4fLV^2}{WD}$$

when h = Head lost by friction,
f = Coefficient of resistance = 0·005,
L = Length of pipe in feet = 600,
V = Velocity of water in feet per second,
W = Weight of a cub. ft. of water (lbs.) = 62·5,
D = Diameter of pipe = $\frac{4}{12}$.

Substituting the numerical values given, and expressing h in terms of V^2, we have

$$h = 0·576V^2.$$

If there were no loss by friction, we should have

$$\frac{P_A}{W} + \frac{V_A^2}{2g} = \frac{P_B}{W} + \frac{V_B^2}{2g},$$

when the suffix B indicates the section through which the water issues into the atmosphere, but as the total head at the point B has been diminished by h feet,

$$\frac{P_B}{W} + \frac{V_B^2}{2g} = \frac{P_A}{W} + \frac{V_A^2}{2g} - 0·576V^2.$$

As V_A indicates the velocity of the water at a circular section which is 4 in. in diameter, and V is the velocity of the water through a 4-inch pipe, $V = V_A$, and hence

$$\frac{P_B}{W} + \frac{V_B^2}{2g} = 100 - 0·576V_A^2.$$

P_B, which is the pressure of the water as it issues from the nozzle, is atmospheric, and as, in assigning 100 ft. as the total initial head of the water no account was taken of atmospheric pressure, it follows that P_B must also be taken as 0, and hence

$$\frac{V_B^2}{2g} = 100 - ·576V_A^2.$$

If the area of the section at A through which the water flows is denoted A_A, and the area at B, A_B, we have

$$A_AV_A = A_BV_B.$$

Hence the velocity at A may be expressed in terms of the velocity at B, that is :

$$V_A = \frac{A_B}{A_A}V_B.$$

$A_B = \frac{\pi}{4}\left(\frac{2}{12}\right)^2$ and $A_A = \frac{\pi}{4}\left(\frac{4}{12}\right)^2$, therefore

$$\frac{A_B}{A_A} = 0·25.$$

Hence $V_A^2 = (·25V_B)^2 = 0·0625V_B^2$.

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Substituting this value of V_A^2,

$$\frac{V_B^2}{2g} = 100 - \cdot 576 \times \cdot 0625 V_B^2 = 100 - \cdot 036 V_B^2$$

From this,

$$V_B^2 = \frac{100}{\cdot 036 + \frac{1}{2g}}.$$

If H is the height in feet to which the water will rise after leaving the nozzle, then

$$H = \frac{V_B^2}{2g}.$$

Hence,

$$H = \frac{100}{\left(\cdot 036 + \frac{1}{2g}\right) 2g} = 30\cdot 3 \text{ feet.}$$

THERMOMETER. — A centigrade thermometer gives accurate readings when its bulb and stem are at the same temperature; if the bulb of this thermometer is maintained at a temperature of t°C., while the mercury in the stem, from the zero graduation onwards, is at a lower temperature t_1°C., what temperature will the thermometer indicate?

Coefficient of cubical expansion of mercury . . . . . = 0·0001815.
Coefficient of linear expansion of glass . . . . . = 0·0000083.

At t_1° let the volume of the thermometer tube between two consecutive degree divisions be equal to v; also, let us assume that the graduations are marked on the glass of the thermometer stem. Let the observed reading of the thermometer be θ°; then the mercury enclosed in the stem, between the zero and the θ graduations, is at a temperature t_1°, and its volume is equal to $v\theta$. If the temperature of the stem were raised so as to be equal to that of the bulb (*i.e.*, to t°C.), the mercury in the stem would occupy the space of t divisions. Let m be the coefficient of cubical expansion of the mercury, while g is the coefficient of cubical expansion of the glass. Then, when θv c.cs. of mercury are heated through $(t - t_1)$°C., the volume at the higher temperature is equal to $\theta v\{1 + m(t - t_1)\}$. Also, the volume of the tube which occupies t divisions would be tv c.cs. at t_1°, but at t° this volume would be equal to $tv\{1 + g(t - t_1)\}$. Thus

$$\theta v\{1 + m(t - t_1)\} = tv\{1 + g(t + t_1)\}$$

$$\theta = \frac{1 + g(t - t_1)}{1 + m(t - t_1)} \cdot t.$$

Let $t = 300$°C., while $t_1 = 20$°C. Since the coefficient of cubical expansion is equal to three times the coefficient of linear expansion of a substance, $g = 0\cdot 000025$ nearly. Then

$$\theta = \frac{1 + 280 \times 0\cdot 000025}{1 + 280 \times 0\cdot 000185} \times 300$$

$$= \frac{1\cdot 007}{1\cdot 052} \times 300 = 287\cdot 1°.$$

HEAT.—A metal ball at a temperature of t_0°C. is placed in the middle of an enclosure, of which the walls are maintained at 0°C.; six minutes afterwards the temperature of the ball is 300°C., and after another minute it is 250°C. Find the value of t_0, assuming Newton's law of cooling.

According to Newton's law of cooling, the rate at which a body loses heat by radiation is proportional to the difference between its temperature and the temperature of its surroundings; hence, if the specific heat of the body is constant, its rate of fall of temperature is proportional to the difference between its temperature and the temperature of its surroundings.

Let the temperature of the ball at any instant be equal to t°C.; then, since the difference between its temperature and the temperature of its surroundings is t°, at the end of a short interval of time its temperature will be equal to $(t - at) = t(1 - a)$, where a is a constant depending only on the length of the short interval of time and the dimensions, mass, and specific heat of the ball. At the end of the next short interval of time, equal to the first interval, the temperature will be equal to that at the beginning of this interval—*i.e.*, $t(1 - a)$—multiplied by $(1 - a)$, or $t(1 - a)^2$. If there are n of these intervals in a minute, the temperature at the end of a minute will be equal to $t(1 - a)^n = kt$, where $k = (1 - a)^n = a$ constant depending only on the dimensions, mass, and specific heat of the body. At the end of the second minute the temperature will be equal to k^2t, and at the end of m minutes the temperature will be equal to k^mt. Hence the temperatures at the ends of equal successive intervals of time form a geometrical progression.

The initial temperature of the ball being t_0, its temperature at the end of six minutes will be equal to k^6t_0: this is equal to 300°C. After another minute (*i.e.*, at the end of seven minutes) its temperature will be equal to k^7t_0, and this is equal to 250°C. Thus

$$\frac{k^7t_0}{k^6t_0} = k = \frac{250}{300} = \frac{25}{30}.$$

Then,

$$k^6t_0 = \left(\frac{25}{30}\right)^6 t_0 = 300;$$

$$\therefore \quad t_0 = 300 \times \left(\frac{30}{25}\right)^6 = 300 \times (1\cdot 2)^6.$$

$$= 896°\text{C}.$$

INTER. B.Sc.—Could you kindly give me a list of Mathematical Books suitable for honours in Mathematics for the Inter. B.Sc.? I have taken the "more advanced Mathematics of the Matriculation Examination."

It is a far cry from Matriculation to Inter. B.Sc. Honours in Mathematics, in fact, farther than to B.Sc. Pass.

Geometry: Besant's Geometrical Conics; Russell's Pure Geometry.

Algebra: C. Smith's or Hall and Knight's Higher Algebra, using Chrystal's Algebra (Part I.) for reference.

Theory of Equations: Burnside and Panton, leaving out the theory of invariants, while supplementing the treatment of determinants by Scott's Determinants.

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Coordinate Geometry: C. Smith's Conic Sections; C. Smith's Solid Geometry.

Trigonometry: Hobson's or Hall and Knight's Elementary Trigonometry, and Locke's Higher Trigonometry.

Calculus: Williamson's Differential and Integral, supplementing with Greenhill's Calculus, especially for hyperbolic functions.

Differential Equations: Page's.

Statics: Minchin's Statics, Vol. I., using Vol. II. for theory of attractions and general theory of forces.

Hydrostatics: Minchin's, supplementing with Besant's Hydromechanics.

Dynamics of a Particle: Routh's or Tait and Steele's.

B.Sc. (Lond.):—I am much exercised by the recent changes in the Mathematical Syllabus. Can you suggest books which would cover the drawing syllabus satisfactorily?

The drawing syllabus may mean much or little. Probably the following course will be found sufficient.

Hall and Knight's Elementary Graphs, the chapter on the graphic representation of functions in Briggs' and Bryan's Algebra, and the chapter on special curves in Lamb's Infinitesimal Calculus. For graphical work in connection with conics, the methods for finding centre, asymptotes, axes, etc., as explained in Smith's Conics, must be supplemented by actual drawing to scale. For projective geometry, the elementary treatment by Budden in his Elementary Pure Geometry should be mastered, and then Professor Henrici's article on modern or projective geometry, in the Encyclopædia Britannica, or Russell's Pure Geometry.

In the last three works only those parts should be read which bear directly on the syllabus.

It must be clearly borne in mind that understanding a graphical construction is not enough—the actual construction must be made.

TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

DEAR SIR,—Permit me to point out a slight mistake in the solution of the problem headed "Theoretical Mechanics," page 391 of the April issue of your magazine. In the equation

$$x\cos\theta = \frac{v^2}{r} - \frac{2T}{m}\cos\frac{2a}{2}$$

and in the two equations following, the "$\cos\frac{2a}{2}$" should read "$\cos^2\frac{a}{2}$," otherwise the final step in the solution is invalid.

Trusting this will be of some service to you,
I beg to remain,
Yours, etc.,
W. R. SINCLAIR.

1, Stratford Villas,
Heaton, Newcastle-on-Tyne.
April 22nd, 1905.

To the Editor of TECHNICS.

DEAR SIR,—In the April number of TECHNICS you were good enough to call the attention of readers to that very useful instrument, the clinograph, of which there are several modified forms in use. Fig. 1 shows a slight alteration which can be made with a pocket-knife, which greatly increases its usefulness. This will be apparent from the figure; in the form commonly used the edge can only be brought to coincide with a line by trial, whereas in that shown to the right of Fig. 1 the concentric portion is brought to the line and the blade swung round to coincide with the line without any trial. The advantage of this can only be fully appreciated by those who have to use such an instrument over complicated diagrams; but I am sure that your readers will find the above useful if you give them the opportunity.

Yours truly,
H. J. TOOGOOD (Engineer).

The Poplars,
Elland, Yorks.
May 13th, 1905.

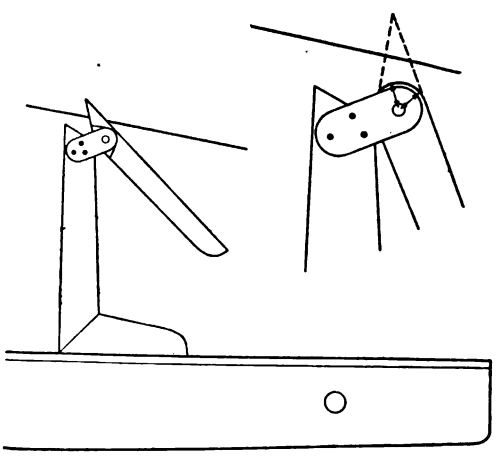

FIG. 1.—THE CLINOGRAPH, ORDINARY AND IMPROVED FORMS.

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INDUSTRIAL PROGRESS

Manufacturers are invited to assist in making this section of TECHNICS *as interesting as possible by forwarding particulars of their latest specialties.*

DISC GRINDERS.

THE employment of grinding machines for circular work of all kinds is extending with great rapidity; it is becoming evident that by its use work can be finished more accurately and quickly than by other means. It is also necessary, in a great variety of work, to produce flat surfaces, such as facings for machine parts, strips, keys, and many other items; in such cases the shaping or milling machine is generally used followed by draw-filing. All this takes time; and the result cannot be compared, either for truth or finish, with work done on the disc grinder. Fig. 1 shows the disc grinder made by Messrs. C. W. Burton, Griffiths & Co., 1, 2, and 3, Ludgate-square, Ludgate Hill, E.C. One of the chief points about this machine is the rapidity with which a piece can be finished, owing to the device by which the piece can be quickly clamped (Fig. 2). The time actually used in grinding may be estimated in seconds, owing to the high velocity of the grinding disc, which runs at twice the speed that would be safe for an emery wheel. Any material can be operated on, whether tool steel, cast iron, gun metal, or brass. Surfaces can be ground at any given angle, and a definite and measured amount of stock can be removed at will, making the machine useful in the fitting-shop, while a flat and true face can be obtained on an engine brass or similar piece. Segments of circles, which are expensive to machine by ordinary methods, can also be quickly finished by the disc grinder.

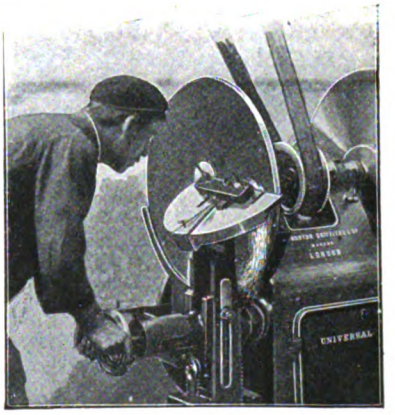

FIG. 1.—DISC GRINDER (BURTON & GRIFFITHS).

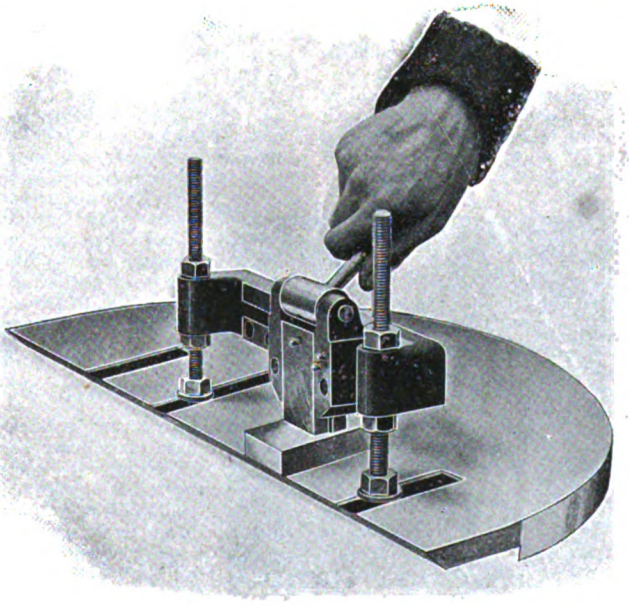

FIG. 2.—CLAMPING DEVICE (BURTON & GRIFFITHS'S DISC GRINDER).

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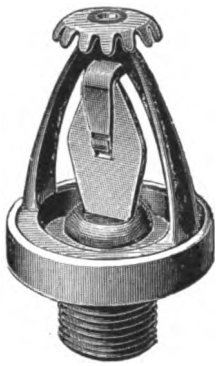
The discs range from 10 inches to 42 inches in diameter by $\frac{9}{16}$ inch thick; they are made of steel specially annealed, finished dead true, and secured to spindle face plates. Micrometer feeds are obtained from a 1-inch screw, ten threads per inch, together with an 8-inch hand wheel divided into one-thousandths of an inch; an adjustable top is fitted, making it possible to produce a number of pieces, alike in length or thickness, to within one-half of a thousandth of an inch. The table for carrying the work (Fig. 1) can be inclined at any angle up to 45°, and indexes are fitted to measure its movement. They may also be rocked across the face of the disc to any required position.

THE GRINNELL AUTOMATIC SPRINKLER.

THE special purpose of the Grinnell Sprinkler is to arrest fire in its incipiency, through the agency of the fire itself. It is thus adaptable to the protection of



Closed.

FIG. 3.—VALVE OF GRINNELL SPRINKLER.

Open.

FIG. 4.—VALVE OF GRINNELL SPRINKLER.

all kinds of property, and being perfectly automatic it requires no human intervention to operate it.

Lines of horizontal distributing pipes are fixed at intervals of 8 or 10 feet along the ceiling of each room, and are connected with larger vertical pipes supplied from the public water mains, an elevated tank, or any source of supply that will keep the water in the pipes under constant pressure. To each line of distributing pipes, at intervals of 8 or 10 feet, automatic sprinklers are attached. Should a fire break out in any part of a protected building, the heat at once rises to the ceiling, where the temperature very soon rises high enough to melt the solder (which fuses at 155° F.), when the elastic valve of the sprinkler is released, and water is discharged profusely over the fire.

Fig. 3 shows the sprinkler closed, while Fig. 4 represents the same open for the discharge of water. The glass valve of the sprinkler is pressed against the edge of an opening in an elastic diaphragm by a strut composed of three pieces joined by fusible solder. When the solder is softened by the heat of the fire the strut falls to pieces; the glass valve, no longer held to its seat, is thrown up by the spring of the diaphragm, aided, of course, by whatever pressure there may be within the pipes. The escaping water impinges upon a deflector and is scattered in all directions in the form of spray (Fig. 5). This sprinkler, made by Messrs. Mather & Platt, Ltd., of Park Works, Manchester, has the magnificent record of having extinguished 7,500 incipient fires, and this list is increasing at the rate of about three outbreaks extinguished per day.

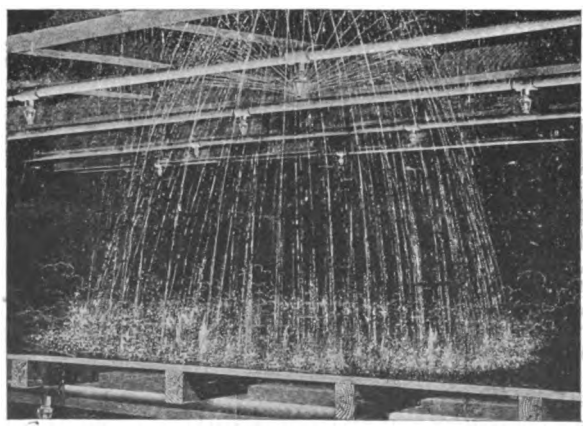


FIG. 5.—GRINNELL SPRINKLER IN OPERATION.

LUX LAMPS.

THE Lux Lamp, made by the Anglo-Swedish Lighting and Heating Syndicate, 86, Leadenhall-street, London, E.C., was described in the May number of TECHNICS (Industrial Progress, p. vi.); the following short synopsis of the advantages of the lamp may be of interest:—

1. There is always constant pressure, so that the lamp gives the same light after many hours burning as when first lit.
2. No filter used, consequent upon the scientific construction.
3. Free from danger, as a mixture of carbonic acid and hydro carbon is not explosive.
4. Filling with petroleum is only necessary two or three times a year.

The total cost of the burning of the Lux light is, for 200 c.-p. ½d. per hour, and 700 c.-p. ½d. per hour, and the lamps themselves are the cheapest of their kind, ranging from £2 to about £14.

The Lux lamps have been accepted for use by the Royal State Railways in Sweden, Austria, Russia, and Germany, and by the State Government Railways in Germany (over 200 stations), and in Sweden over 250 stations are lighted by the Lux lamps; which goes far to safely recommend them to all industries where a steady, brilliant, and economical light is required.

AUTOMATIC MOTOR STARTERS.

AUTOMATIC starters are designed to take the place of ordinary hand-operated resistances for starting up electric motors. Where the rheostat is manually controlled there is always the liability of cutting resistance out too rapidly, and so accelerating the motor at too high a speed, thus overloading the motor and frequently overheating the resistance of the rheostat. Further, the hand-operated rheostat can only be used to start the motor when the operator is actually present; and if it is required that the motor be started and stopped

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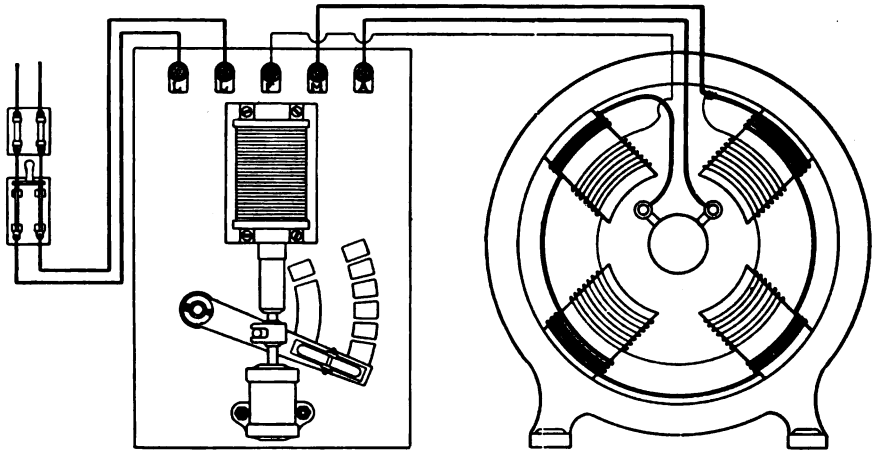

FIG. 6.—DIAGRAM OF AUTOMATIC MOTOR STARTER, CONNECTED TO COMPOUND MOTOR.

frequently, personal attendance is necessary on every occasion.

Automatic motor starters have been designed for the purpose of avoiding these difficulties,

1. By taking the control of the rate at which the motor is started out of the hands of the operator.

2. Movements of the motor itself or varying levels in a water tank, or certain reciprocating parts of the machinery can be utilised to cause the starter to operate as required.

The automatic motor starter supplied by Messrs. Geipel and Lange, of 72A, St. Thomas'-street, London, S.E., consists primarily of a rheostat having the resistance connected to a series of contacts by a lever, which, as it passes from step to step, cuts resistance out of the armature of the motor, accelerating it to full speed. This motion is imparted by a solenoid excited from the line. The circuit of the solenoid is made independently of the motor, and, as there is only a small current to be carried, is wound with wire of small gauge. The operation is as follows :—

The circuit of the solenoid is closed by means of a switch placed at any distance from the motor-starter. It immediately begins to draw up the contact lever of the rheostat, first closing the main circuit and exciting the armature with all resistance in, and then cutting this resistance out step by step, until the motor is accelerated to full speed. When the circuit of the solenoid is broken by opening the switch, the rheostat lever runs back over the contacts, throwing resistance into the armature and then opening the circuit. The

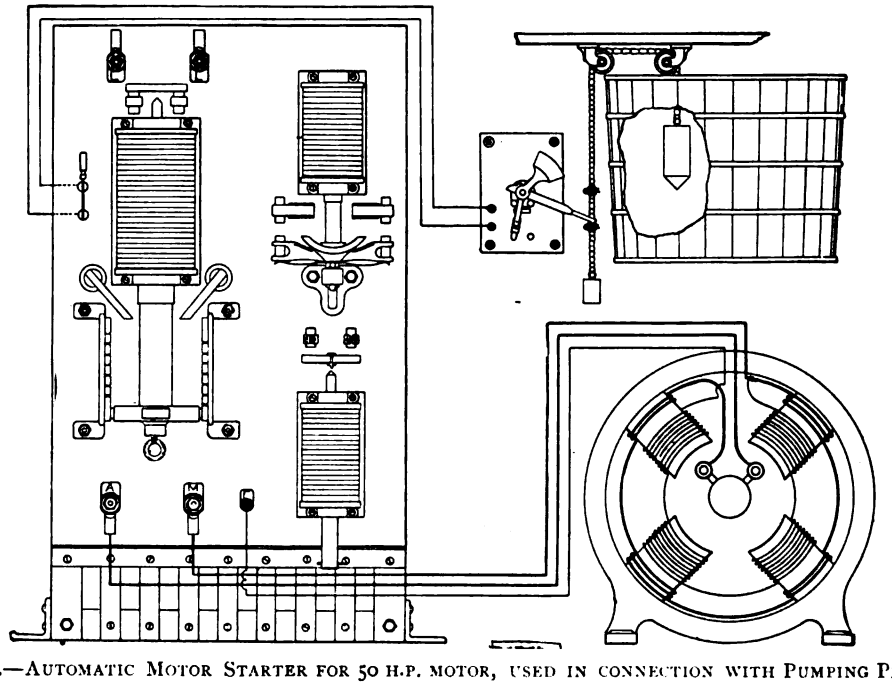

FIG. 7.—AUTOMATIC MOTOR STARTER FOR 50 H.P. MOTOR, USED IN CONNECTION WITH PUMPING PLANT.

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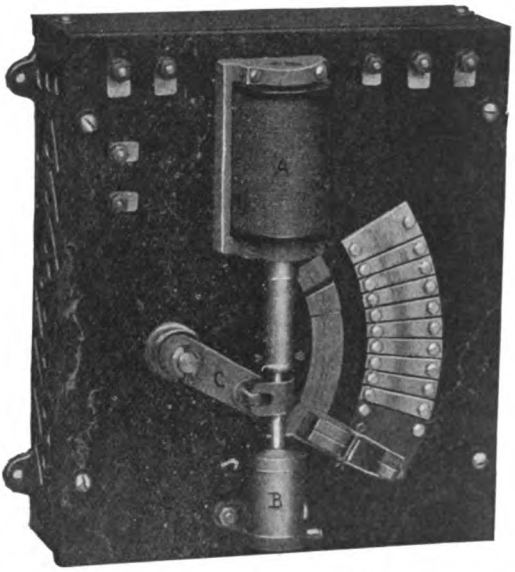

FIG. 8.—AUTOMATIC MOTOR STARTING SWITCH.

rate at which the rheostat lever cuts resistance out is controlled by an air dash pot, the leakage from which is regulated in a simple manner, providing for variation of the period of starting over a wide range.

This type of starter can be advantageously used in connection with industrial machinery, as, for example, with pumping plants where the water level in a tank is required to be kept at a constant level without manual intervention. In this case an automatic motor starter can be connected to the motor, and wires from the solenoid taken to a small switch opened and closed as a float in the tank rises and falls; as the level in the tank falls and the motor is required to start pumping, the switch is closed, the solenoid excited, the motor started, and the water raised to its former level. When this stage is reached the float opens the solenoid switch and stops the motor.

Another application is to organ blowing, for which, in a similar manner, the switch is opened and closed by the bellows as they rise and fall. When the bellows are nearly empty and the motor is required to start, the automatic switch is caused to operate by the closing of a small shunt switch closed by the movement of the bellows.

For hydraulic accumulators the motor starter can be arranged to start up and stop the motor as the accumulator rises and falls, in the same manner as above described.

Fig. 7 shows the exact connection and arrangement of a 50 h.-p. motor starter used in conjunction with a pumping plant.

NEW HEAVY TRACTION SWITCH.

THIS switch (Fig. 9), which has been designed by Cecil Hodges & Co., London, is a new departure in switch work for heavy currents.

The contact, instead of being made by a solid copper knife working on the flat surface of a copper spring, as in the old type of knife switch, is made by laminated copper brushes working in solid copper jaws. Each lamination thus makes its own contact, ensuring that the whole of the contact surface is utilised, and doing away with any heating.

All the current-carrying parts are of ample sectional area for the nominal rating of the switch.

Mechanical strength is another feature, the switch-handle being a malleable iron casting, which has a separate bearing independent of the electrical contact.

The wear on the brushes is taken up by spare liners, which are readily inserted.

The switch has a long, quick break, suitable for breaking heavy currents up to 600 volts.

The whole is of the best workmanship, and the iron casting being heavily nickelled on the edges, gives a very satisfactory finish.

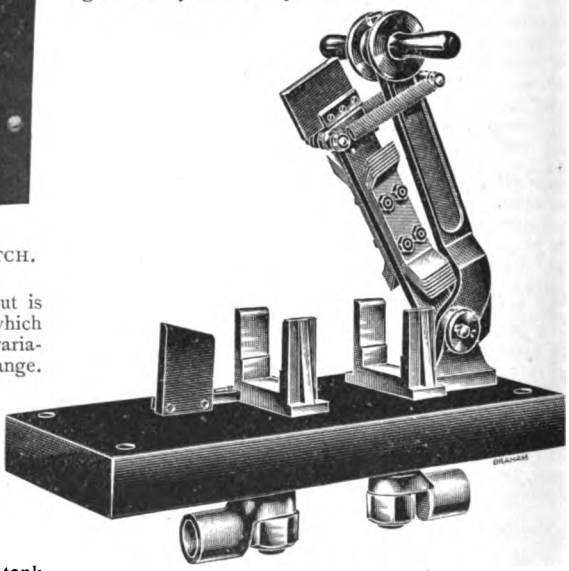

FIG. 9.—HEAVY TRACTION SWITCH.

A NEW HORIZONTAL MILLING MACHINE.

A NEW Plain Milling Machine has recently been brought out by Messrs. Alfred Herbert, Ltd., Coventry. Fig. 10 gives a good idea of the general appearance of the machine. It will be noticed that, in the main, it conforms to the generally accepted practice. A considerable amount of attention has, however, been given to the easy manipulation of the machine on the part of the operator, and to the completeness of the feed range, in which respects the machine is unique.

The leading dimensions are as follows:—Longitudinal feed 34 inches, cross movement 9 inches, vertical adjustment 20 inches.

The overchanging arm is a solid steel bar of large diameter. The arm brace is a single casting, rendering it very rigid. The spindle has a long conical bearing in front and an adjustable parallel bearing behind, and may be adjusted for diameter or thrust independently. The table is exceptionally deep, and is lubricated from the front, so that it is not necessary to remove the vice or other fixture when the table requires oiling. It is attention to small points such as these, in the design, that renders a machine much more convenient and easier to work than one in which these matters are overlooked.

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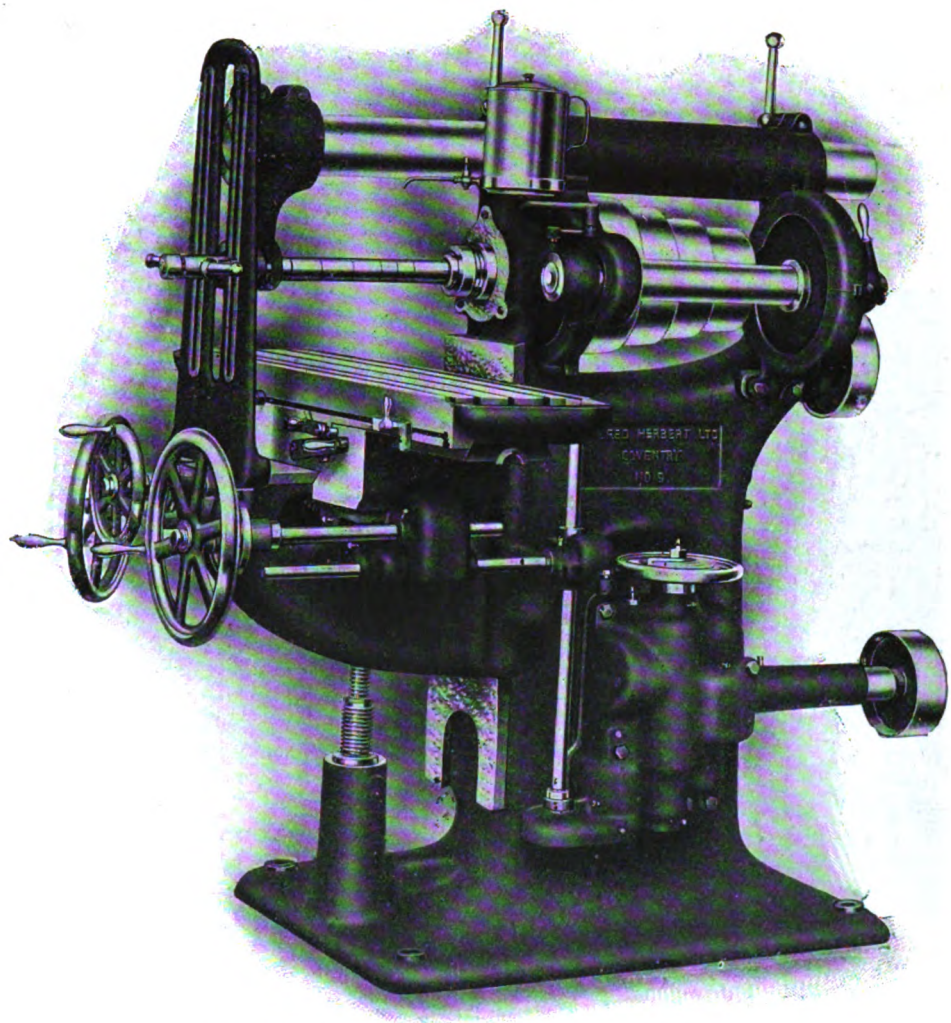

FIG. 10.—HERBERT'S HORIZONTAL MILLING MACHINE.

The table is fed by a screw which does not rotate, is not splined, and is always in tension. The movements of the table, cross-slide, and knee are controlled by three handwheels, all within easy reach of the operator without moving from his working position. The handwheel on the right moves the table longitudinally, and by means of gearing gives a very fast travel. The handwheel in the middle is for the cross adjustments, and on the left-hand side for the vertical adjustments. All these movements are provided with graduated dials reading to 0·001 inch. The elevating screw is telescopic, so that it is not necessary to cut a hole in the floor.

The firm's new Patent Dial Feed Motion, by which the change from any one feed to another is obtained by simply turning the handwheel, is fitted to this machine. On a disc attached to the handwheel are stamped the various feeds, to obtain any one of which it is merely necessary to turn the disc round until that feed is opposite a pointer.

The feed is arranged so that it may be driven from the spindle or direct from the countershaft, and the disc is stamped with two sets of feed ranges—when driven from the spindle in inches per revolution, and when driven from the countershaft in inches per minute. When the feed is obtained from the spindle, the driving-pulley is geared to revolve at twice the spindle speed, so that the feed belt, which is very wide, has a high velocity. Messrs. Herbert recommend the feed of all milling machines to be driven direct from the countershaft, and follow this practice in their own works, where they have some 50 machines, both horizontal and vertical, in operation. It will be noticed that there are no telescopic shafts or universal joints used in the feed transmission gearing.

The knee is a box casting entirely closed in on the under side, and having a bearing on the column carried up above the horizontal surface of the knee. This form of knee, although more expensive to machine, is more rigidly supported than where the bearing on the column finishes below the horizontal surface. The cross-slide is unusually long, forming a very efficient support to the table.

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The whole design of the machine bears witness to careful thought, and is pleasing in its effect. Three sizes of this machine, including a smaller and a larger one, are at present being built. The method of manufacture is on strictly modern lines, all machine work being done to jigs and templates, and all cylindrical work that fits being finished at dead centres by grinding.

AN UP-TO-DATE WINDOW FRAME.

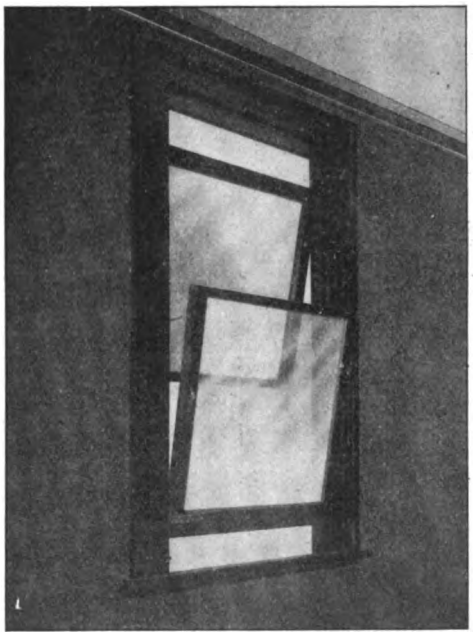

FIG. 11.—NEW WINDOW BALANCE.

THE firm of Recorders, Ltd., 171, Queen Victoria-street, London, E.C., are supplying the window balance, illustrated in Figs. 11 and 12, which on account of its many obvious advantages, should quickly become popular. Ideal ventilation is obtained by its use, as the window can be opened at the top, in the middle, and at the bottom ; further, all draughts can be avoided. The largest window can be opened or shut quite easily. All weights, pulleys, cords, and box frames are done away with. An important advantage is that existing sash windows can be altered at a trifling expense to suit the new balance. The windows are perfectly water-tight and do not rattle. The whole of the outside of the window can be cleaned from the inside of the room, as shown in Fig. 12.

FIG. 12.—WINDOW, BALANCE PRINCIPLE, IN COURSE OF CLEANING.

PORCELAIN SWITCH FUSE.

THIS switch fuse is another of Hodges & Co.'s specialities. It is designed, as will be seen in the illustration, with a heavy porcelain handle, provided with metal ends to take the fuse strip, which is passed through the centre. The bore of the handle is specially large, and being lined with asbestos, obviates any risk of breakage when the fuse blows. These fuses are also made in the "open type," with the fuse strip under the handle, which is protected by a porcelain guard.

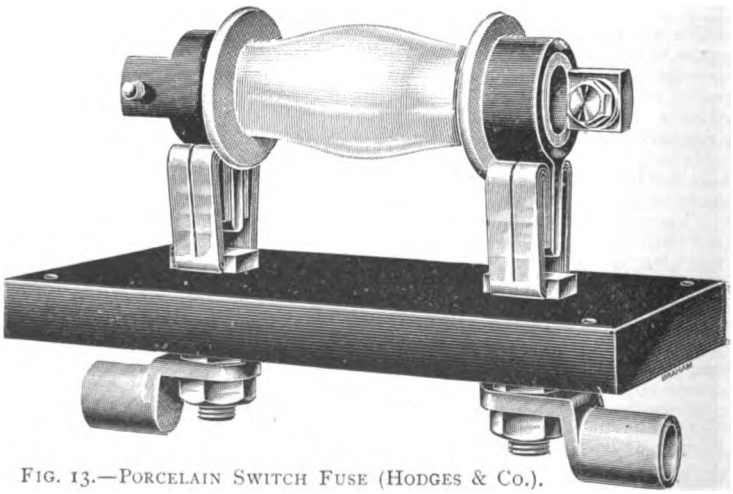

FIG. 13.—PORCELAIN SWITCH FUSE (HODGES & CO.).

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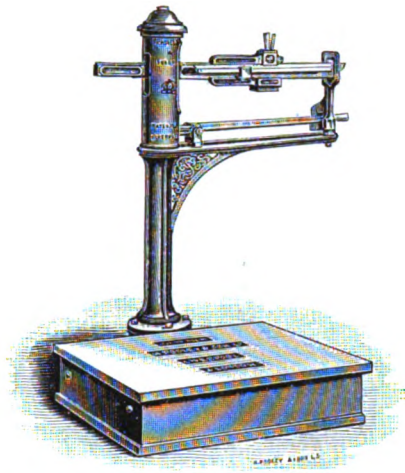

FIG. 14.—PLATFORM WEIGHING MACHINE (POOLEY & CO.).

FIG. 15.—PLATFORM WEIGHING MACHINE (FAIRBANKS CO.).

SPECIAL WEIGHING MACHINES.

THERE have been many improvements of late in the production of special machines for weighing barrels, and general raw materials in packages, which are designed to meet the needs of chemical manufacturers and others engaged in industrial operations.

One great advantage of this specialisation is that the sensitiveness of the machines can be adjusted and perfected to a far greater degree than is the case when a general weighing machine has to be designed, to meet, as nearly as possible, the varied requirements of a works.

Although at the first blush it may appear cheaper to have one big machine, careful consideration shows that it is really far more economical (and therefore in the long run cheaper) to use special machines, particularly when deliveries of expensive products, such as certain oils, kegs of pigments, silk hanks, etc., have to be checked for industrial purposes.

Figs. 14 and 15 represent different types of weighing machines. Both Messrs. H. Pooley and Son, Ltd., and the E. and T. Fairbanks Co., have a variety of special platform, scale, and other classes of weighing machines, many of which are of more than ordinary interest to manufacturers, who, we think, will derive both profit and assistance from the catalogues issued by these firms.

IMPROVED MOTOR SPIRIT RESERVOIRS.

A LIGHT, but really strong and trustworthy tank for the storage of motor spirit, and more particularly for use as a reservoir on the car or lorry itself, has long been sought for by motorists, and motor car builders in particular.

By an adaptation of their electric welding system, the Steel Barrel Co., Ltd., of Uxbridge, have succeeded in making both the ideal storage tank, and also a reservoir of special interest to the motor-car and waggon builder.

One great advantage of their reservoirs is that angles and awkward shapes present little difficulty, and an additional seam or two does not introduce strains and liability to leak. Consequently the reservoir can often be placed in a hitherto impossible position, thus saving considerable trouble to the designer and builder, as well as enabling them to provide greater storage capacity. With material like motor spirit, the less need there is to carry loose gallons, the better; while there are obvious advantages in having a reservoir on the car that needs as little refilling as possible.

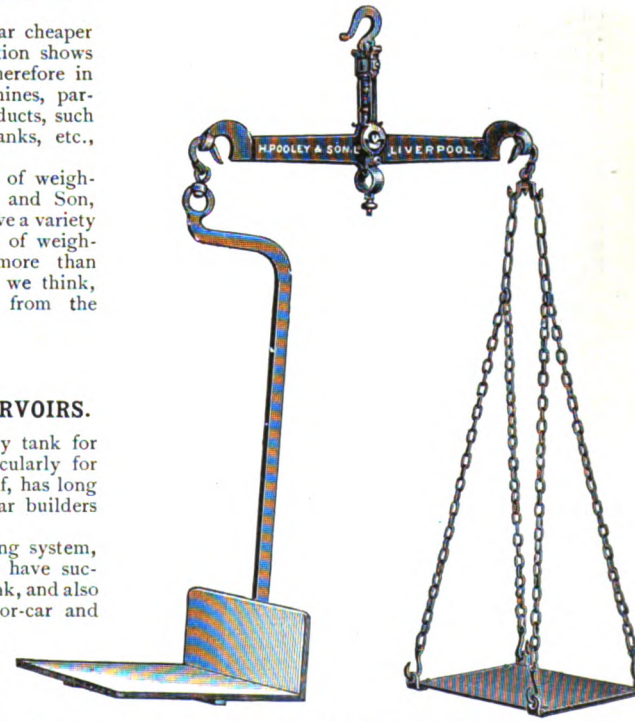

FIG. 16.—BALANCE, FOR WEIGHING HEAVY GOODS (POOLEY & CO.).

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LIGNUM VITÆ ACID TAPS.

ACID taps of many styles, made from useful and ingenious alloys, have long been invaluable accessories in chemical manufacturing operations, though of course, the ideal material is *lignum vitæ*. Unfortunately the extreme difficulty of working this hard wood has kept it out of the field of practice.

Of late, however, advances in wood turning have made it possible to produce these taps satisfactorily, and also at a reasonable figure. They are cut from the solid in one piece up to ½ in. bore. A perfect seating for the plug is ensured, as the pitches of the plug and collar are absolutely identical. This end is achieved by special chucking devices, while the plug is accurately turned, and the collar bored, by the same tool in the same lathe. A straight flow is thus obtained, a feature of great importance when dealing with highly-corrosive or expensive liquids. In fact, the taps present all the advantages of the ordinary wooden tap, only they are applicable to a great variety of uses for which the former is wholly unsuited, and they are less likely to split. Valves up to 1½ in. bore are also made in the same material. The taps range from 21*s.* a dozen and the valves from 30*s.* each.

THE NODON VALVE.

FIG. 17 represents the latest developments of the Nodon valve—a device for converting alternating monophase or polyphase current into rectified or continuous current. The general principle on which the Nodon valve is designed depends upon the fact that if an attempt is made to transmit an electric current from an aluminium plate into dilute sulphuric acid, a film is formed on the plate and the passage of the current is prevented. A current sent in an opposite direction is, however, not in the least opposed. Hence, if an apparatus containing electrodes of lead and aluminium, immersed in dilute sulphuric acid, is placed in series with an accumulator across alternating mains, the phase of the alternating current, which tends to send a current from the aluminium to the lead, will produce no current, while the opposite phase will charge the accumulators. The Nodon valve has been very much improved of late, and it can be used for rectifying alternating currents for traction purposes. In comparing the advantage of this with the use of a motor generator the following figures are of interest.

Cost of motor generator, foundations, fixtures, and switch-board, to convert an alternating current so as to give fifty amperes at 120 volts, is about £155; the efficiency of the arrangement being 49·1 per cent.; the cost of a Nodon rectifier, with switch-board and transformer or economy coil, to serve the same purpose, is £68, and the efficiency 65 per cent.

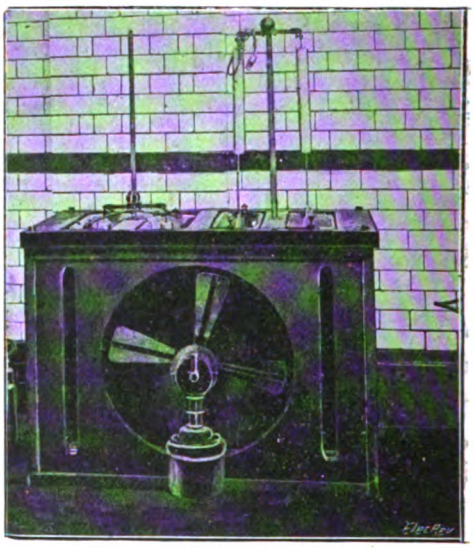

FIG. 17.—THE NODON VALVE.

It has been found that at temperatures above 120° F. the efficiency of the Nodon valve rapidly diminishes. To prevent any chance of such a rise of temperature, the Nodon valve, made by Messrs. Harry Snowdon, Balfour House, Finsbury-pavement, London, E.C., is supplied with a fan shown in Fig. 17.

AUTOMATIC CONVEYORS.

FIG. 18 represents a dry sugar band conveyor made by Watson Laidlaw & Co., of Glasgow. The band is made of rubber and canvas having great strength and flexibility, but impervious to moisture and not liable to stretch unduly. This conveyor may be used to elevate sugar or other similar substances to a moderate height, the angle of elevation depending on the nature of the substance. The end carrying roller is made with adjustable gear, to enable the band to be kept at a proper degree of tightness.

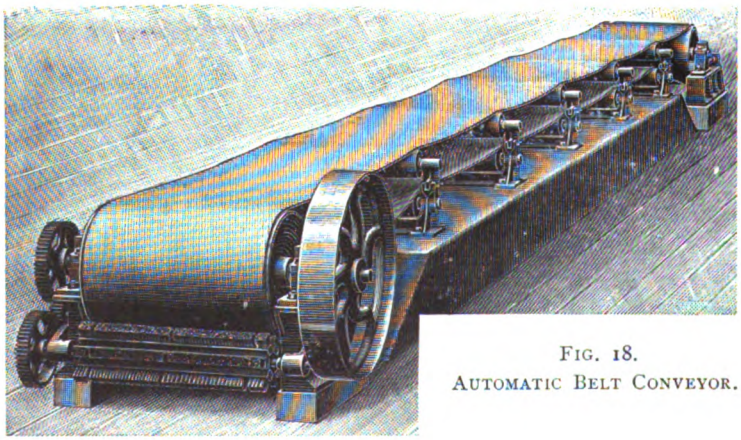

FIG. 18.
AUTOMATIC BELT CONVEYOR.

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INDUSTRIAL PROGRESS

Manufacturers are invited to assist in making this section of TECHNICS *as interesting as possible by forwarding particulars of their latest specialties.*

HORIZONTAL LOG BAND SAW.

THE most striking introduction in sawmill machines is undoubtedly Kirchner's large Patent Horizontal Log Band Saw, which we illustrate. Fifteen or twenty years ago, timber merchants, home and foreign, used to cut their timber with either the old travelling table rack bench, or with the vertical or horizontal log frame. Both are to-day antiquated from a technical as well as from an economical point of view. The rack bench is very wasteful both in power and timber, and at the present time of keen competition, when every point of economy must be studied, such machinery cannot be used to advantage, except for cutting up small crooked timber into gate-posts, fencing, etc. Vertical and horizontal timber frames are too slow. The band mill, against which there was a great prejudice in the beginning, has been introduced during the last ten years; Messrs. Kirchner & Co. were the pioneers of this machine in Europe. The most recent introduction is the horizontal log band saw, which the makers claim as the most powerful and rapid machine in existence for the conversion of home and foreign timber, whilst the quality of the work is unsurpassed. Space does not allow us to give the many interesting details which our readers in the timber trade would like to have, and we can only advise them to communicate with the makers. We shall restrict ourselves to giving the comparisons between the results of the former old sawmill machines and the present new ones.

Capacity.—Kirchner's new horizontal log band saw will cut, under the guarantee of the makers, hard wood, such as English oak and elm, at rates of speed exceeding 60 feet super. per minute (counting the actual time of cutting). A timber merchant near London, who has one of these machines, recently cut 1,000 feet superficial of hard wood (coffin boards) within half an hour. This half-hour includes the waste of time incurred in running the carriage back and setting the machine for the next cut. Let us compare the capacity of the older machines: A single-blade horizontal reciprocating frame saw has a daily output which does not come up to what this horizontal log band saw does in half an hour; a vertical timber frame, cutting with 15 to 20 saws at one operation, requiring a much larger staff of men to attend to it, could not, under the most favourable conditions, do as much in ten working hours as the horizontal log band saw can do in two or two and a-half hours; the comparison with the old style circular rack bench is more unfavourable still.

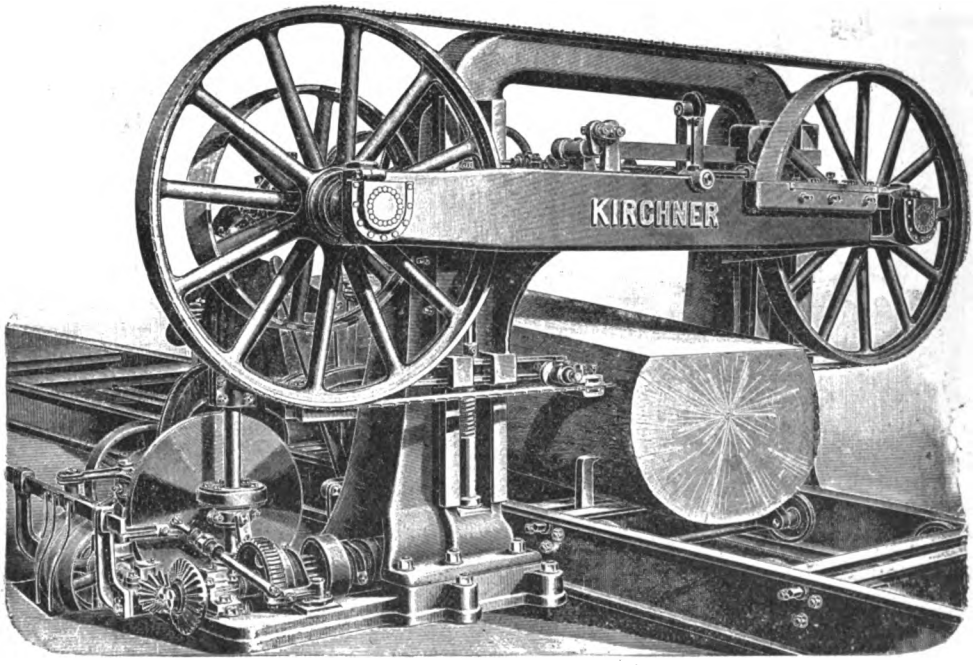

FIG. 1.—KIRCHNER'S LOG BAND SAW.

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Economy.—This is another important factor with which timber merchants have to count, and here the band mill is the ideal tool. The gauge of the band sawblade is smaller than of any type of machine, and timber 5 feet wide is converted with 18 or 19 gauge saws, as compared with 12 and 13 gauge in vertical and horizontal timber frames, and 4 or 5 for circular rack benches. The saving of timber effected by use of the band saw will pay for the whole cost of sawing, and it leaves so great a surplus every year that it goes a good way towards paying for the machine itself.

Another important point in favour of the horizontal log band saw is that the sawyer has a chance, after each cut, to examine the grain of the timber, which is most necessary in the conversion of oak and elm, which woods frequently develop cracks and hollows inside.

THE STRATTON SEPARATOR.

THE Stratton Separator (Fig. 2) is a device for separating particles of suspended water from steam; a rotational motion is imparted to wet steam, and the liquid particles, being heavier than the steam which they displace, are projected to the outside of the current by the centrifugal force acting on them.

The separator consists of a vertical cylinder with an internal central pipe extending from the top downward for about half the height of the apparatus, leaving an annular space between the two.

A nozzle for the admission of the steam is on one side, the outlet being on the opposite side, or on top, as may be most convenient in making the connections.

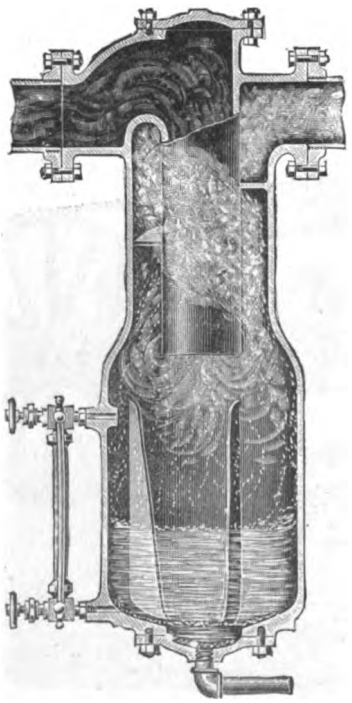

FIG. 2.—"STRATTON" SEPARATOR.

The lower part of the apparatus is enlarged to form a receiver of considerable capacity, thus providing for a sudden influx of water from the boiler.

A suitable opening is tapped at the bottom of the apparatus for a drip connection, and a glass water-gauge shows the level of the water in the separator at all times.

The current of steam, on entering, is deflected by a curved partition, and thrown tangentially to the annular space at the top side of the apparatus. It is thus whirled around with all the velocity of influx, producing the centrifugal action which throws the particles of water against the outer cylinder. These adhere to the surface, so that the water runs down continuously in a thin sheet around the outer shell into the receptacle below, while the steam, following in a spiral course to the bottom of the internal pipe, abruptly enters it, and in a dry condition passes upward and out of the separator, without having once crossed the stream of separated water, all danger of the steam taking up again such water after separation being entirely avoided.

As the rapid rotation of the current of steam also imparts to the separated water a whirling motion which tends to interfere with its proper discharge from the apparatus, the separator has been provided with wings or ribs projecting inwardly at an acute angle to the course of the current, thus breaking up this whirling motion and allowing the water to settle quietly at the bottom, whence it passes off through the drain pipe.

A MAGNETIC SEPARATOR.

THE great loss entailed by breakages caused by iron getting into almost any kind of grinding machinery is well known, and the difficulty of entirely separating it from the material to be ground will be as readily admitted.

The magnetic separator has been designed to meet this difficulty and supply the demand for a trustworthy means of separating iron from materials to be ground, and to deal with materials which have hitherto been beyond the capabilities of magnetic separators.

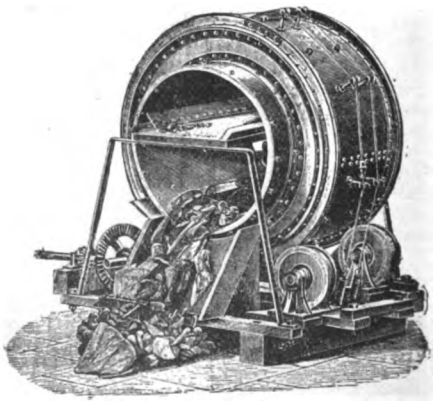

FIG. 3.—MAGNETIC SEPARATOR.

In dealing with rough materials, such as bones, hand labour is almost universally used, but this mode is quite untrustworthy, either on account of the want of sufficient care of the operatives, or on account of the difficulty in distinguishing the iron, when coated with foreign matter, from the other materials. Sometimes, also, iron is found lodged in hollow bones, which renders its discovery by hand-picking very improbable.

With ordinary magnetic separators there has always been the liability of a piece of iron being carried over

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the magnets on top of, or with, a large piece of bone or other material ; and as in these machines there is only one chance for the magnets to catch it, it thus escapes and passes to the mill with the material to be ground.

This separator, represented in Fig. 3, is made by the Hardy Patent Pick Co., of Sheffield. It consists of a cylinder placed with its axis not quite horizontally, but with one end higher than the other, so that when revolved, material introduced at the highest end will gradually make its way out at the lower end.

This cylinder is placed upon rollers which enable it to be easily revolved, and leaves the inside without obstruction for the passage of the material through it. Inside the cylinder are about twelve magnets, extending along the greater part of its length, and forming slightly projecting ribs inside it in the direction of its length. These magnets are excited by a dynamo, with which they are automatically connected and disconnected during the revolution of the cylinder. A tray or shoot is fixed inside the cylinder, near the top, but not connected with it in any way. When the magnets, during the revolutions of the cylinder, are passing over the tray or shoot, they are disconnected from the dynamo, and so drop on the tray any pieces of iron or other magnetic substance they have picked out of the material ; and during the remainder of their revolutions with the cylinder they are in connection with the dynamo, and so magnetised and ready to pick out any magnetic substance.

By this arrangement, it will be readily understood that the material is turned over and over many times as it passes through the interior of the cylindrical separator, and the powerful magnets are constantly having the material passed over them as they revolve with the cylinder, and as they ascend to the top they carry up with them, out of the material, any iron or other magnetic substance that they attract, holding this until it is over the tray or shoot, into which they drop it as they are disconnected with the dynamo. It is thus impossible for a piece of iron to pass through the separator without coming in contact with the magnets.

It is estimated that a piece of iron, from entering one end of the separator, would have to pass over the magnets about 120 times before it could escape at the other end, and as these magnets will lift up and deposit on the tray pieces of iron varying from the size of a small nail to the weight of many pounds, it will be seen that the chances of iron passing through the separator with the other material are very remote. As a matter of fact, almost all the iron is picked out by the time it has travelled with the material about six inches from the end of the cylinder where it enters, and as the cylinder is about six feet long, there is plenty of spare room for safety.

A NEW BELT FASTENER.

FIG. 4 represents a belt fastener made by A. M. Lewis, 47, Hunter's-road, Hockley, Birmingham. The method of using this to join up a belt will be easily understood from Fig. 5. Suitable holes are punched in the belt by means of special punches supplied by the maker, the screwed rod is removed from the fastener, and the arms of the latter are threaded through the perforations near the two ends of the belt ; subsequently the removable rod is screwed into position, and the belt is then securely joined. A notable point is that there are no sharp points or projections which are likely to prove dangerous. It is claimed that the fastener will outlast the belt with which it is used.

HIGH-SPEED STEAM DYNAMO.

MESSRS. MATHER & PLATT, of Salford Iron Works, Manchester, are supplying a high-speed single-acting enclosed engine suitable for steam pressure from 70 to 180 lbs. at engine stop valve developing from 13 to 25 kilowatts and running up to 500 revolutions per minute (Fig. 6).

This type is especially useful for private house and estate installations, for pilot circuits in mills, paper and chemical works, in engine-rooms aboard ship, in

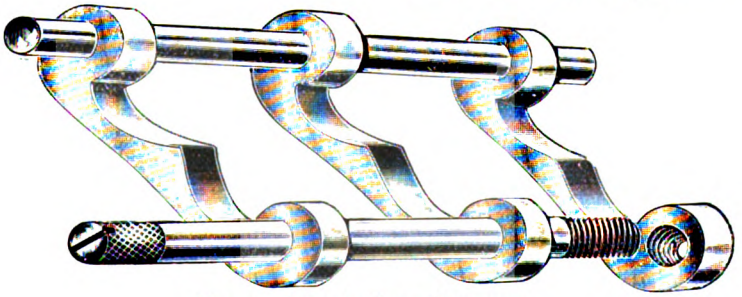

FIG. 4.—LEWIS'S BELT FASTENER.

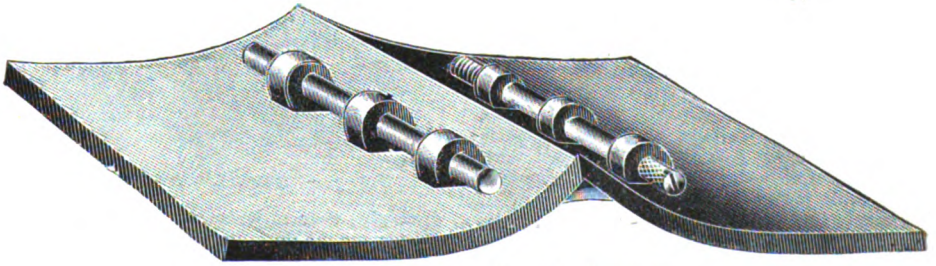

FIG. 5.--BELT JOINED BY LEWIS'S FASTENER.

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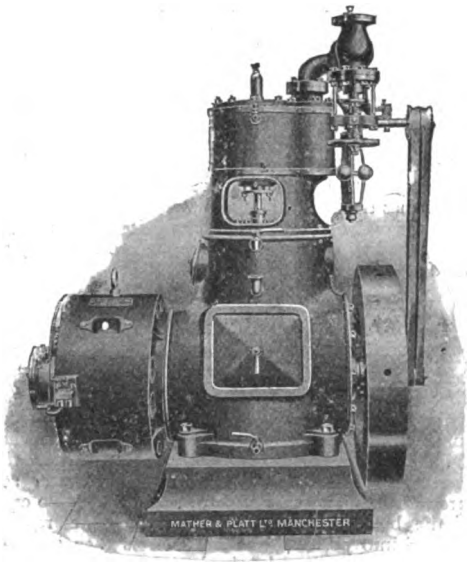

FIG. 6.—HIGH SPEED ENGINE AND DYNAMO.

all confined places, and wherever the prevalence of dust has to be reckoned with. It finds, moreover, extended application in connection with the driving of circulating pumps for condensing and other plants requiring water service, as well as for ventilating and blowing fans, exciters for large alternators, and for a variety of other purposes.

A special type of electrical generator has been designed for bolting direct to the frame of the engine, rendering an extended bedplate unnecessary, and thereby reducing the cost of foundations to a minimum, since the floor space occupied by such plants is exceedingly small.

The following general specification sets forth the details of construction more fully :—

The *engines* are of the single-acting high-speed enclosed self-lubricating type, and are made either simple or compound, to suit the steam pressure available and power required. The exhaust can be arranged for discharge into a condenser or to atmosphere.

The *cylinders* are of close-grained iron, cast in a piece with the valve chest, and accurately bored and faced for attachment to the *frame*, which is likewise of cast iron, machined on top for connection to cylinder. The frame is carefully bored to form a large diameter guide, which, in conjunction with a plunger-shaped cross-head, constitutes the *air buffer*.

The *valves* are of the piston-type, and are connected to their rods by taper bore and nut, being driven by eccentrics enclosed within the engine.

The *bed-plate* is of cast iron, box section and ribbed internally to ensure strength with lightness. It serves as a reservoir for holding the mixture of oil and water into which the cranks dash at each revolution, thus lubricating the pins, bearings, and working parts generally. The outer bearings are provided with glands to prevent the escape of oil from the chamber, the whole being cooled by water circulating pipes.

The *cranks* and *crank shaft* are of steel, in one piece, the former being carefully balanced by weights opposite the crank pin.

The *connecting, piston, eccentric, and valve rods* are all of steel, and carefully designed for their work, the connecting rod being always in compression.

The *fly-wheel* is of the solid cast iron disc type, and is made sufficiently heavy to ensure steady running. It is mounted at opposite end of bed to dynamo or pump, and provided with barring and lifting holes in the rim.

The *governor* is of the centrifugal ball type, and can be adjusted to give variations of speed while the engine is running. It is driven by a double belt or ropes from the projecting end of crank shaft.

The *fittings* include stop valve, lubricators, save-alls, filler, drain-cocks and their connections. The cylinders and the valve chests are coated with non-conducting composition, and neatly lagged with planished sheets.

For lubricating, the crank chamber should be filled with water to about 1½ inches below the under side of the crank shaft. A good class of mineral cylinder oil should thereafter be poured on the top of the water, the best proportion being about one part of oil to ten parts of water. As the mixture gets heated through working, it will very gradually evaporate, and care must be taken to see that there is always a sufficiency of water and oil in the chamber. A brass plug is provided in the filling funnel attached to the bed-plate, and this plug indicates the correct level of the mixture.

Castor oil should not be used in the crank chambers.

A WATER-SOFTENING PLANT.

FIG. 7 represents the Beissel Water-Softener, made by Messrs. Rose, Downs & Thompson, Ltd., Hull. In this plant the method of softening the water is the same as in other plants for the same purpose. Its

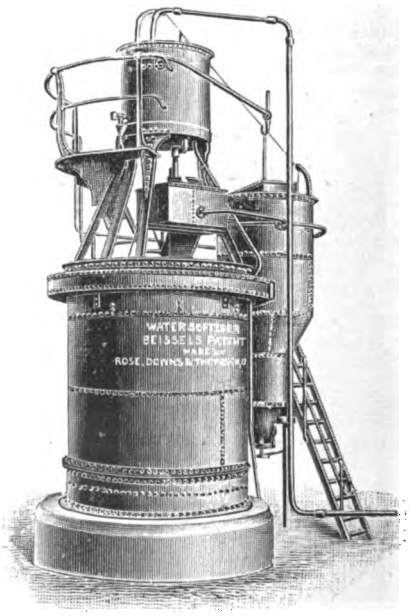

FIG. 7.—"BEISSEL" WATER SOFTENER.

distinctive feature, however, is the method used to quickly remove the sediment. This is done by dividing the turbid water into very thin layers, so that no filtration is necessary. The chief part of the apparatus

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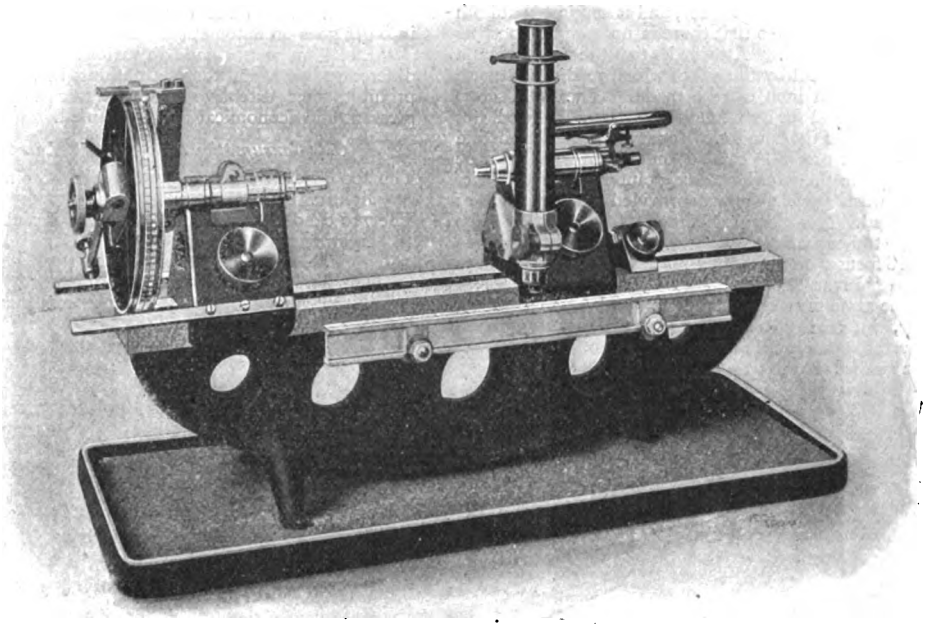

FIG. 8.—MEASURING MACHINE (NEWALL ENGINEERING COMPANY).

is the settling tank, the bigger cylindrical part on the left. Iron stanchions on the top of this tank support a smaller cylindrical vessel which is divided into two compartments; one contains the hard water and the arrangements for regulating its inflow, while the second compartment is filled with alkali (usually soda solution). Between this top tank and the bigger settling tank is shown a smaller square tank; this contains a regulating arrangement for bringing together the hard water, the soda solution, and the solution of quicklime, all in the right proportions. As already mentioned, a settling tank is divided into a large number of thin layers by means of metal sheets on which the sediment collects. It can be removed at the end of the day by opening the blow-off valve for about one minute.

A NEW MEASURING MACHINE.

IN the past, accurate measuring machines have not been extensively used, doubtless on account of their great cost. The Newall Engineering Co., Ltd., of Atherton's Quay, Warrington, have, however, recently placed on the market a measuring machine which combines the advantages of very great accuracy with minimum cost. An elevation and part section of the machine are shown in Fig. 9, while Fig. 8 represents the complete machine. The back stop of the machine is held in position by a spring, and any pressure on the back stop acts on a lever which moves a sensitive spirit-level. By this means the pressure to which the object to be tested is subjected can be accurately read. The screw is of a coarse deep pitch,

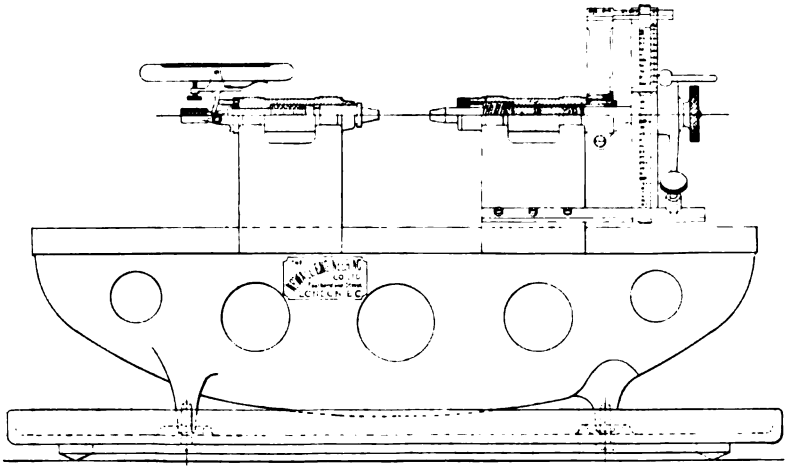

FIG. 9.—SECTION AND ELEVATION OF MEASURING MACHINE.

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giving ample wearing surface, and is supported at both ends on bearings, so that there is no weight upon its effective portion. Attached to the screw is a graduated wheel by the aid of which readings as small as $\frac{1}{100000}$ of an inch can be made. The main screw can be rotated for quick movement by a knurled nut at the end of the spindle. For slow movement a fine adjustment screw is carried on an arm which can be clamped to the wheel at any point by an eccentric, and thrusts against the bar provided on the front of the head. For measurements exceeding one inch the back stop can be set so that the microscope shown in Fig. 8 focuses on the cross wires one of the inch readings of an "Invar" scale.

The same firm also make standard end measuring rods, internal micrometers, internal limit gauges, adjustable external limit gauges, and other appliances of a similar character.

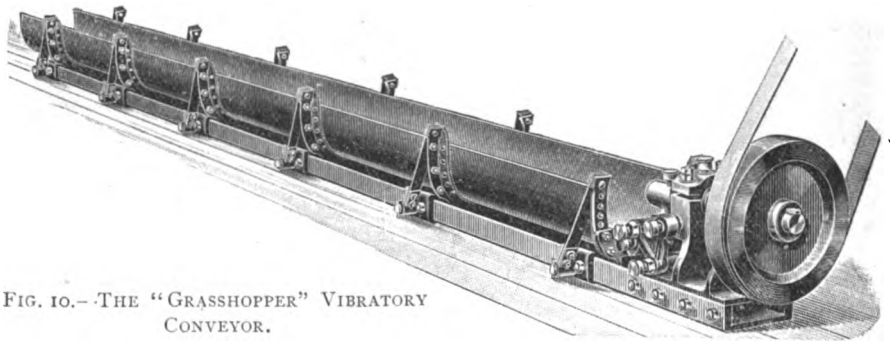

FIG. 10.—THE "GRASSHOPPER" VIBRATORY CONVEYOR.

A VIBRATORY CONVEYOR.

MESSRS. WATSON LAIDLAW & CO., of Glasgow, are supplying the vibratory conveyor (called the "Grasshopper" conveyor) which is represented in Fig. 10. This conveyor consists of an open trough or gutter, without any screws, spirals, or scrapers, and is supported by springs fixed as shown in the illustrations. A quick oblique vibratory motion is transmitted to the trough, which causes the material to move rapidly forward. There is no clogging or sticking, as the vibration of the trough is sufficient to keep it clean. This very important function is performed so perfectly that a change from one grade of sugar to another may be made without the lapse of any material interval of time, and at little or no risk of the different colours of sugar commingling.

THE LUX INCANDESCENT PETROLEUM LAMP.

IN this lamp (Fig. 11) mineral oil is vaporised and burnt as a non-luminous flame which heats a mantle similar to that used in gas lighting. The oil used is ordinary mineral oil (refined petroleum), and as a rule the cheaper grades of oil give the best results. This oil is stored in a tank placed either inside the lamp-post or in the immediate neighbourhood; and connected with this tank is a cylinder containing carbonic acid gas, the pressure of which forces the petroleum up through a fine tube towards the burner, over which is suspended a specially-prepared incandescent mantle such as is used in intensified gas lighting.

When lighting the lamp, the necessary heat for vaporising the petroleum is obtained by burning a small quantity of methylated spirit in a specially-devised trough beneath the burner; but when once the lamp is started, the burner-flame itself supplies the requisite heat, and the conversion of the petroleum into gas goes on automatically and continuously.

"Lux" lamps are made in various designs and of different powers, and there is nothing in their cost to prohibit their extensive use wherever a powerful, pleasant and economical light is wanted.

Oil Consumption in "Lux" Lamps.

The 200 candle-power lamp consumes 1·8 pints in ten lighting hours.

The 700 candle-power lamp consumes 6 pints in ten lighting hours.

Incandescent Mantle Renewals.

Taking average results, an incandescent mantle will last:—

In a 200 candle-power lamp, about 200 lighting hours.

In a 700 candle-power lamp, about 150 lighting hours. With careful treatment these figures are often largely exceeded.

Carbonic Acid Consumption.

The amount of carbonic acid gas used is very small, being from 5 to 10 lbs. for an average year's working of a small and large lamp respectively.

The "Lux" lamp is a brilliant light-giver, smokeless, inodorous, inexplosive, and economical.

In addition to being well adapted for indoor lighting, the "Lux" lamp is particularly suited for street illumination, and for the lighting of railway stations, factories, markets, ships and shipyards, and other large areas. In this respect it possesses a great advantange over both gas and electricity, inasmuch as each lamp is self-contained, so that all necessity for disturbing the streets for the laying of gas pipes or electric connections is avoided.

The lamp is supplied by the Anglo-Swedish Lighting and Heating Syndicate, 86, Leadenhall-street.

FIG. 11.
"LUX" INCANDESCENT PETROLEUM LAMP.

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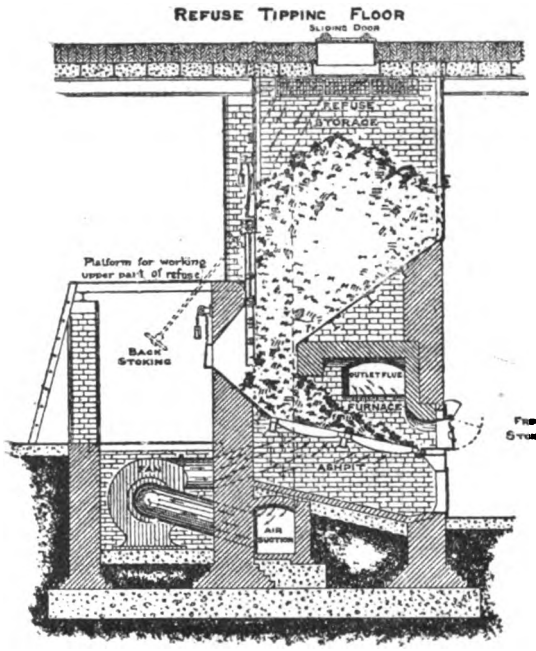

FIG. 12.—BAKER'S REFUSE DESTRUCTOR.

BAKER'S PATENT REFUSE DESTRUCTOR.

THE refuse destructor represented in Fig. 12 has been designed by Messrs. Joseph Baker and Sons, Ltd., of Willesden Junction, London, N.W., with a special view to the complete consumption of all noxious gases. For many years it has been realised that the only proper way of destroying refuse is to do so in an enclosed furnace, and a number of furnaces of different types have been designed for this purpose. But the difficulty has arisen that, no matter how carefully fed, a great deal of the refuse is only partially consumed, and noxious gases result; the great heat necessary to burn them and split them up into innocuous constituents not being attainable. To overcome this difficulty, and also to provide a really economical method of utilisation of heat, the Baker Patent Destructor has been devised.

It will be seen (Fig. 12) that the refuse destructor is approached by means of an inclined plane, or is situated below the normal level of the ground, and the inlet for the refuse is by horizontal sliding door to the refuse storage hopper. From this hopper the refuse descends on to the lower or burning hearth, which is in fact the furnace proper. Forced draught is used, and a small fan is set under the back stoking passage; this fan draws its air partly from the refuse storage hopper and partly from the outside air, and forces it through fire bars and the hottest part of the furnace, and thence to the outlet flue, which runs transversely across the furnace and away to the boiler. The arch over the outlet flue is made of fire-brick blocks, with spaces between to allow a large quantity of heat to play upon the dead plate at the bottom of storage hopper, upon which the refuse lies. All the refuse, before it comes down to the furnace proper, is thus thoroughly dried and ready for complete combustion; and all the gases which are given off in this process are carried down through the side wall of the cell and through the furnace. This special feature of the Baker Patent Refuse Destructor has commended it to sanitary inspectors and engineers all over the world.

Another important feature is that in practically all of the Baker plants no provision is made for storing the refuse outside, but a very large refuse storage hopper is provided which will enable enough refuse to be stored for burning for at least ten or twelve hours; in this way plants are always found to be unobjectionable, and although, in some cases, put to work in the most densely populated districts, they have given rise to no complaints of any description. It will be noted that the refuse itself is used as a seal between the storage hopper and furnace, and that a back stoking door is provided for pulling down the refuse from storage hopper on to the burning hearth. With ordinary refuse, however, it is found that the slope of dead plate is sufficient to bring the refuse down naturally as it burns away beneath, and very little stoking is required.

Joseph Baker and Sons, Ltd., have recently completed a large set of refuse destructors in Calcutta, which plant has now been accepted by the Municipality. The same firm are at present at work upon a further installation for the city of Buenos Aires. A very interesting example of Messrs. Baker's work can be seen at the Finsbury Borough Council's Refuse Destructor Works, Phœnix Wharf, Lambeth. Not long ago this refuse destructor was called upon to take something like 100 per cent. overload, owing to the breakdown of another make of destructor; but it proved equal to the occasion, and consumed a very large amount of refuse per diem for some little time without creating any nuisance, despite the fact that this destructor is working in a densely-populated neighbourhood.

INDEXED CASES FOR DRILLS.

THE indexed case for drills represented in Fig. 13 is supplied by Messrs. Charles Churchill & Co., Ltd., 9 to 15, Leonard-street, E.C. The drills are contained in holes arranged in concentric circles in the block. Over them is a revolving cover with holes to

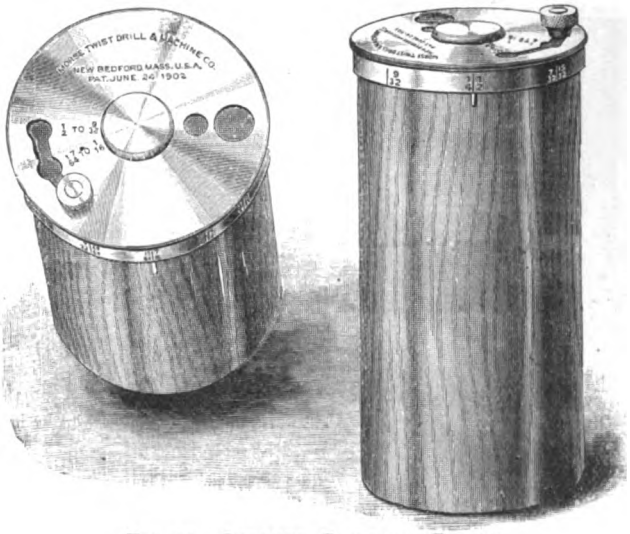

FIG. 13.—INDEXED CASES FOR DRILLS.

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correspond. Around the rim of the cover are stamped the sizes of the various drills contained in the case.

Between the cover and block is a swing shutter also having holes corresponding with the circles in the block. This shutter moves with the cover, but can also be moved independently by means of the knob shown working in a slot in the cover. At various points on this slot are enlargements into which fits a button on the knob, and when so fitted the shutter is held firmly in position. Against each of these enlargements, except one, are figures indicating the range of sizes contained in some one of the concentric circles in the block.

When a drill of a certain size is required, turn the cover round until the figures on the rim, indicating the desired size, come opposite the index mark in the block. Then pull up the button on the knob controlling the movement of the shutter until it is disengaged from the slot, push it until the knob is opposite the figures covering the size wanted, and let the button drop into place. The hole in which that particular drill lies will then be uncovered, and by inverting the case the drill will drop out. To close the case, push the knob to the end of the slot against which there are no figures.

AUTOMATIC CENTRE PUNCH.

THE Automatic Centre Punch represented in Fig. 14 is entirely new in design, and combines features that make it much more convenient and accurate for laying out work to be machined or drilled than the ordinary centre punch and hammer. In designing this tool every care has been taken to combine lightness and simplicity with durability. The various parts are proportioned to withstand the most severe usage to which tools of this character should be subjected. All parts are of steel proportioned and adjusted to avoid liability of getting out of order. The parts most subject to wear are carefully hardened.

FIG. 14.—AUTOMATIC CENTRE PUNCH.

The tool is self-contained, the striking mechanism being enclosed in the knurled handle, which is of such a size and form as to be conveniently held in the hand. The small size is about $5\frac{1}{4}$ ins. long and $\frac{5}{8}$ in. diameter; the large one $6\frac{1}{4}$ ins. long and $\frac{3}{4}$ in. diameter.

Advantages.—When following a line or establishing a point by the intersection of lines one hand can be free to guide the point or hold the magnifying glass; and, after the point has been located, it is not apt to slip and lose the setting, as a downward pressure of the handle releases the striking block and makes the impression. Another advantage appreciated by mechanics is that the punch marks are all of uniform depth, and therefore more easily and accurately followed than when of varying depths.

This tool is made by Messrs. Charles Churchill and Co., Ltd., 9 to 15, Leonard-street, E.C.

PORTABLE PRIMARY BATTERIES.

MESSRS. SIEMENS BROS. & CO., LTD., are supplying a portable cell (Fig. 15) for ignition purposes, which combines the advantages of both wet and dry cells. Essentially it is a wet cell, and consequently the electrolyte can be renewed; but it is so thoroughly closed that, unless severely damaged, the liquid cannot escape. It contains no acid, and there is no creeping of salts. These cells have a large output relative to their weight. They can be kept indefinitely in a dry condition, or may be conveyed from place to place, either charged with solution ready for immediate use, or they may be filled in a few minutes. After use they

FIG. 15.—PORTABLE PRIMARY BATTERY.

can, if desired, be emptied of solution and rinsed out once or twice with warm water, and then laid aside for future use. A special salt which gives the best result is provided, but ordinary salammoniac can be used.

For motor cycles three No. V. cells giving $4\frac{1}{2}$ volts can be used; they occupy only a small space, and are also suitable for motor cars, for which size XII. is recommended. Each of these cells weighs about 3 lbs. $4\frac{1}{2}$ oz. charged. Three of these cells will give $4\frac{1}{2}$ volts, and four cells 6 volts.

THE RAPID CONSTRUCTION OF A STEEL FRAME WAREHOUSE.

A CONTRACT has just been placed with Messrs. Graham, Morton & Co., Ltd., engineers and contractors, of Leeds, for the construction and erection of a large warehouse at East Quay, South Dock, for the Alexandra (Newport and South Wales) Docks and Railway Co. The building is to be 200 feet long and of 70 feet span, and the whole of the ironwork will be in position eight weeks from the date of the order. This, of course, consists of roof-principals, purlins, rivetted compound steel girders, rolled-steel girders, the usual gutterings, etc., and a specified number of casements constructed to open in the centre. All steel used in the construction is to be of the best quality mild steel. The principals are to be spaced 12 feet 6 inches apart. A louvre will run the whole length of the building. All the work must stand careful testing on the part of the Company's engineer, or his representative.

ERRATUM.

On p. vi. of this section in our April issue, the height of Messrs. Harper, Phillips, and Co.'s trolley base should have been given as 4 inches, instead of 4 feet.

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INDUSTRIAL PROGRESS

Manufacturers are invited to assist in making this section of TECHNICS *as interesting as possible by forwarding particulars of their latest specialties.*

HIGH TENSION MOTOR GENERATOR SET.

REFERENCE was made in this section in the March Number of TECHNICS (p. 296) to a High Tension Motor Generator Set, made by the Lancashire Dynamo and Motor Co., Trafford Park, Manchester. We are now pleased to be able to give further particulars of this machine.

The set (Fig. 1) is designed to run off 10,000 volt 60 period 2-phase mains, and will take current from the Metropolitan Supply Co.'s mains. The continuous-current generator has an output of 460 volts, 550 amperes—*i.e.*, 250 K.W., and the set runs at 440 revolutions per minute, full load speed.

The induction motor has the stator (Figs. 2 and 3) built up of specially selected sheet-iron, and the coils are laid in half-closed slots. These slots are lined with special mica insulating tubes, which extend for some distance on each side of the core.

The rotor (Figs. 4 and 5) is also built up of laminated plates, with half-closed slots; the winding, consisting of copper bar, is laid in these slots, and connected together by heavy copper-end connections. These end connections are held in position by special wedge-shaped rings, thus making a first-class mechanical job of the rotor. The slip rings are of brass, and the brushes of copper gauze.

The continuous-current generator (Fig. 1) is of the multipolar type, provided with six poles. The brush-gear is of the standard type adopted by the firm, and the armature is of the slotted type, bar wound.

The field magnet yokes are of cast steel, circular in shape, and are provided with steel poles of circular or elliptical section, and a special form of pole piece to eliminate sparking. The fields are split across the horizontal diameter, to enable the armature to be readily inspected and repaired. The yoke is provided with brackets lined with white metal, to support the brush ring. Special adjusting screws in the magnet feet are provided, on sizes larger than No. 17, by means of which the air gap may be adjusted in any direction.

The field coils are former wound, insulated with press-spahn, served with tape, and then dipped in an insulating compound and thoroughly baked. Each coil is provided with its own terminals, so that no loose wires project, thus avoiding the danger of the latter being broken off. The coils are held in their

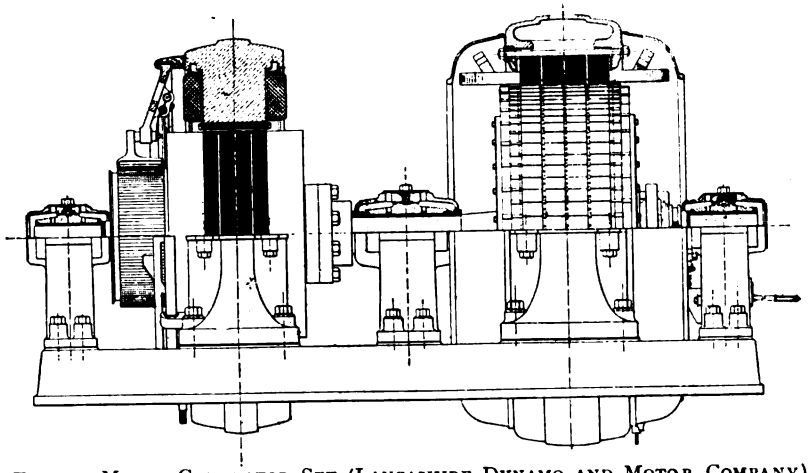

FIG. 1.—MOTOR GENERATOR SET (LANCASHIRE DYNAMO AND MOTOR COMPANY).

FIG. 2.—THE STATOR.

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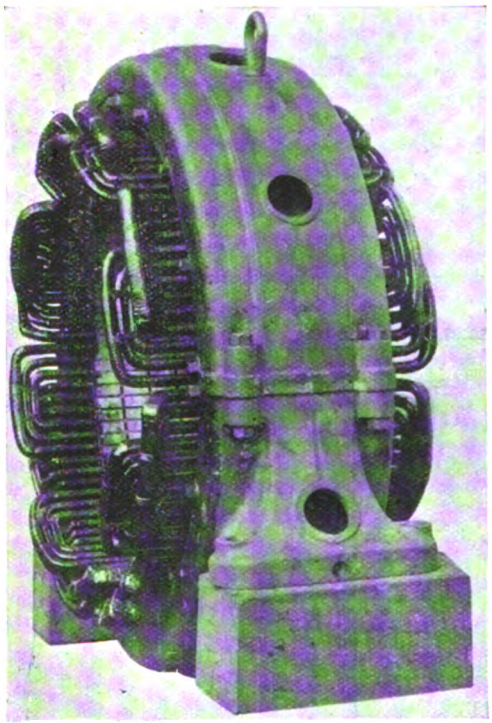

FIG. 3.—ANOTHER VIEW OF STATOR.

places by a brass plate both top and bottom, enabling the air to circulate freely both inside and outside the coil, and ensuring cool running and absence of sweating. A very high insulation resistance is obtained by this method, eliminating the danger of the coils earthing if the shunt current is interrupted. Series coils are of bare copper strip, wound on edge and taped over all.

The commutators are built up under hydraulic pressure, and are made of hard-drawn copper bars of liberal depth, insulated with specially selected mica, which wears evenly with the bars. Micanite is used for insulating the end rings. In the larger sizes the end rings are divided into segments, which are drawn together by special steel rings of wedge-shaped section. In this way the bars are held down with great pressure, but are left free to expand longitudinally; with this method of construction it is almost impossible for a bar to be knocked down by a hammer.

The armatures are of relatively large diameter, with a small armature re-action, and are built up of thin, varnished plates, with slots provided to receive the windings. The armature is further ventilated by brass distance pieces and internal air ducts in the core to ensure cool running. The plates are securely keyed to a cast-iron sleeve, which extends to the bearings on one side, and is formed into a coupling on the other in machines for direct coupling, thus enormously strengthening the shaft and eliminating any strain on the keys in case of short circuit. The commutator is also carried on this cast-iron sleeve. The windings are of the cylindrical barrel type. Each coil or bar is wound on a special former, afterwards taped up, and then dipped in a special insulating compound and dried. A trough of prepared insulation is next put into the slot, and the coil or bar slipped into position; after they are all in

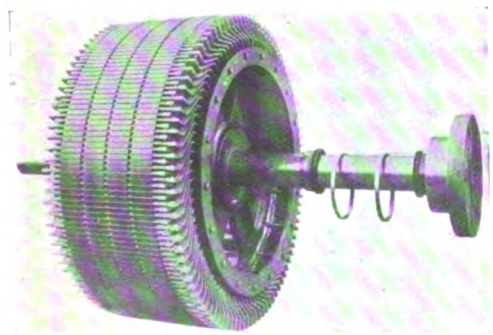

FIG. 4.—THE ROTOR.

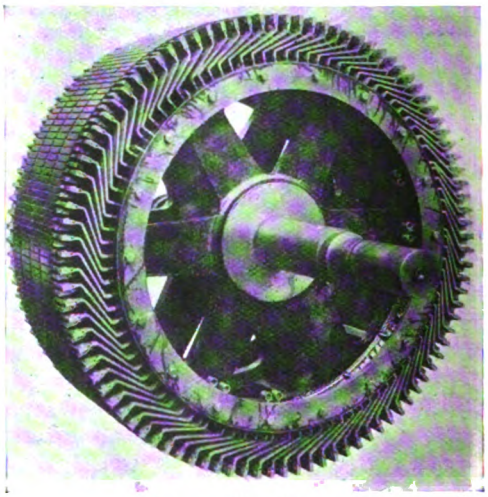

FIG. 5.—THE ROTOR.

place, wood strips are driven into the tops of the slots, which are specially dovetailed, and steel bands wound tightly on and soldered up. The bands are carried in recesses in the core, so that in case the armature touches the fields it is not damaged. The coils or bars are provided with a cast-iron support at each end to prevent oil or dust getting into the windings. The connectors to the commutator are of soft copper strip, soldered into the commutator bar, and bent into a special form to prevent breakage by vibration and expansion. Double oil throwers are provided to prevent any oil leaking into armature or frame of machine. On parallel-wound armatures equalising rings are fitted, and these may, if desired, be put on after the machine is erected and electrically balanced.

MOTOR STEAM FIRE ENGINE FOR LONDON FIRE BRIGADE.

THE first motor steam fire engine built to the order of the London County Council for the London Fire Brigade, by Messrs. Merryweather and Sons, was tested on February 27th at the Greenwich works. The new machine, which is the most powerful of its kind in London, will deliver 500 gallons per minute.

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It is fitted with a quick steam-raising water-tube boiler, fired with a new pattern petroleum burner. The machinery, which is placed vertically between the frames in front of the boiler, consists of a pair of inverted steam cylinders driving two direct and double-acting pumps. The power for propulsion is taken from the crankshaft on this engine by putting a counter-shaft into gear, from which the road wheels are driven by a pair of steel roller chains running over sprocket wheels. The pump pistons can be connected or disconnected from the engine in a few seconds by a simple device, so that only one set of machinery is required for propelling and pumping, thus saving a large number of working parts and consequent complications, which have been serious disadvantages in foreign-built motors. The new engine is steered by hand-wheel, with irreversible gear, and is controlled by levers for steam, reverse, and brakes. A large hose-box is fitted, and eight firemen and an engineer can be carried. The road wheels are of the artillery pattern, fitted with steel rims, solid rubber tyres, and Parson's "non-skids."

It may be mentioned that similar engines are already in use in the fire brigades of Liverpool, Brighton, Portsmouth, Plymouth, Tottenham, Leyland, Heston, and Isleworth, and other British towns, as well as a number abroad.

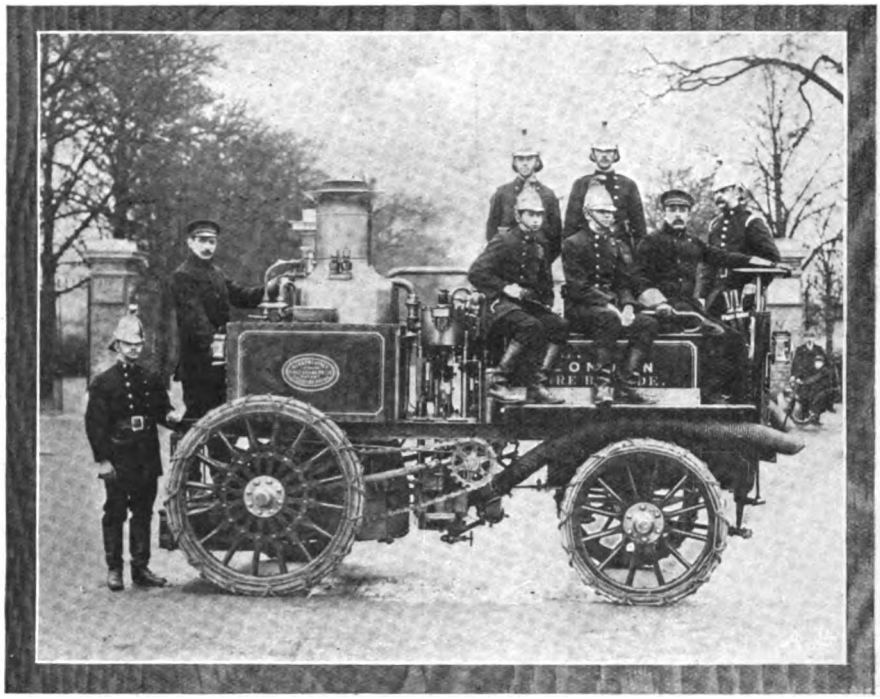

FIG. 6.—STEAM MOTOR FIRE ENGINE.

ARON ELECTRICITY METER.

WE have received from The General Electric Co., Ltd., 71, Queen Victoria Street, E.C., a pamphlet describing the latest form of Aron Electricity Meter made by that firm. Within the last few years the Aron Meter has been very much improved; the following figures, from a test made at the Westminster Electrical Testing Laboratory, show the performance of a direct current meter for fifteen amperes, the direction of current through the pendulums being reversed every ten minutes.

LOSS IN METER.

Shunt Circuit.—Resistance 8,490 ohms. Watts 1·18.

Winding Circuit.—Resistance 1,183 ohms. Watts at instant of winding 8·45; average over a considerable period 0·25 watts only.

Main Circuit.—The drop of potential at full load was found to be 0·516 volt, the power being 7·74 watts.

ACCURACY AT VARIOUS LOADS.

The meter was tested for accuracy throughout the following range, and the errors found were as follows:—

Load Expressed as Percentage of Full Load.	*Error.*
125 per cent. . . .	0·10 per cent. fast.
100 ,, . . .	0·15 ,, ,,
50 ,, . . .	0·15 ,, ,,
25 ,, . . .	0·25 ,, ,,
10 ,, . . .	0·45 ,, ,,
1 ,, . . .	3·50 ,, ,,

THE EFFECT OF VARYING THE PRESSURE.

The meter was run, passing about 1,000 watts, at three different pressures, namely 150, 100, and 70 volts.

At 150 volts the meter registered 0·1 per cent. less than at the normal voltage, and at 70 volts 0·1 per cent. more than under normal conditions.

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VULCANISING MOTOR-CAR TYRES.

It is not the first cost of a car that keeps people from taking up motoring as a pleasure, but the annual cost of keeping it roadworthy; or, in other words, the very serious expenditure needed for tyre repairs. Messrs. Harvey Frost and Co., Ltd., 39, Great Eastern Street, London, E.C., have placed on the market an outfit for repairing and vulcanising tyres. The use of this appliance can be understood from the following description. Let us take, for instance, a serious injury to a tyre, such as a burst five inches long. Instead of putting an ugly and cumbersome patch over the damaged portion, the edges of the

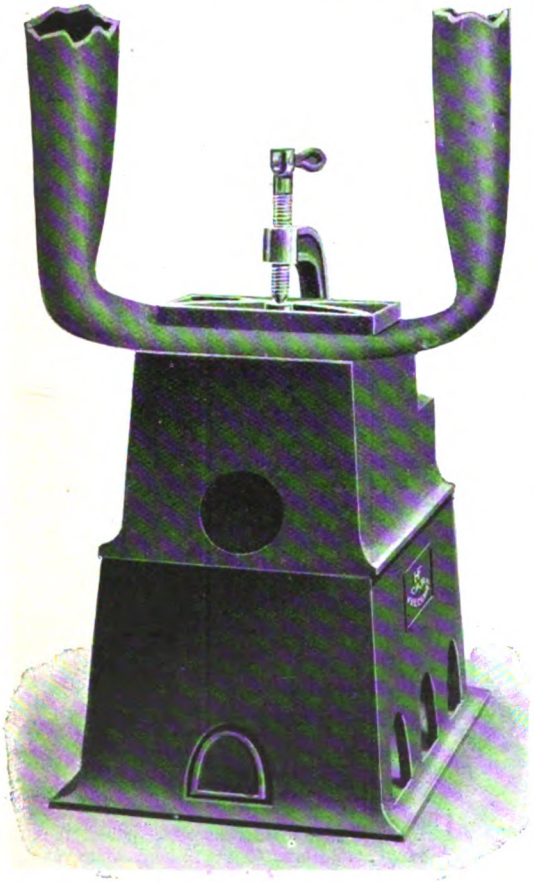

Fig. 7.—Portable Appliance for Vulcanising Tyre.

gash are cleansed, trimmed, filled with "H. F." Plastic Compound, and placed in the vulcaniser; the repair is then "cured" for a sufficient time by heat generated by steam. Subsequently the tyre comes out whole, with the repaired portion almost indistinguishable from the rest of the rubber. The repair is made with pure virgin rubber vulcanised in the manner employed in the manufacture of rubber tyres for over twenty years. The vulcaniser is 9 × 6 × 6 inches in dimensions, and its weight complete is less than 20 lbs. There is absolutely nothing to get out of order, and any person of average intelligence can use it. It can be readily carried on

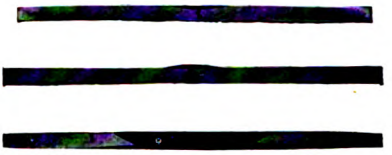

Fig. 8—Sections through Repaired Tyres.

any motor car, and thus the necessity for carrying spare tyres is entirely obviated.

THE INSTALLATION OF AN ECONOMIC COAL-HANDLING PLANT IN A MODERN GASWORKS.

The unique design of coal-handling plant, for which the Lea Bridge District Gas Company have placed the order with Messrs. Graham, Morton and Co., Ltd., Leeds, is to be constructed to the plans of Mr. F. W. Cross, A.M.I.C.E. The plant is very complete; it is, moreover, simple in conception, and promises to be effective in operation. A hydraulic waggon-tipper is provided, capable of raising the ordinary standard railroad waggon to an angle of 46°.

The waggon-tipper is suitable for a working pressure of about 700 lbs. per square inch. The hopper is fitted with a flat-bar screen on the top, so that all the large coal can be broken before passage to the elevator. The under side is arranged to accommodate a jigger feeder for regulating the supply of coal to the elevator. The elevator is of the cased-in type, the dimensions being 18 in. and 45 ft. between centres. It is provided with a breeches shoot at the head, with flap-door, and levers for operating same.

The band conveyor is of the 16 in. standard type, 106 ft. between centres, and capable of conveying 25 tons of coal per hour, at a normal speed of 200 ft. per minute.

A standard travelling throw-off carriage, for delivering the coal on either side of the conveyor, is to run the entire length of the stores. The friction-gear is so arranged as to admit of the carriage running in either direction, as required.

THE LANCASHIRE PATENT BELTING AND HOSE COMPANY, LTD.

In Liquidation.

Messrs. F. Reddaway & Co. have purchased the business of The Lancashire Patent Belting and Hose Co., Ltd., lately carried on at New Bridge Street, Strangeways, Manchester, together with the goodwill, stock-in-trade, trade marks, etc.

The manufacture of hair belting, known as the "Lancashire," and other specialities of the Lancashire Belting Co., will be continued, and purchasers may rely upon receiving the identical goods, under the same marks as formerly supplied by The Lancashire Patent Belting and Hose Co., of which Messrs. Reddaway & Co. are now sole proprietors.

This branch of the business will, from date, be carried on under the management of Mr. S. J. McMechan, formerly proprietor of The Lancashire Patent Belting and Hose Co.

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PROTECTION FROM X-RAY BURNS.

THE dangers incurred by an operator continually using X-ray apparatus were described in the February number of TECHNICS, p. 109. Messrs. Harry W. Cox, Ltd., have placed on the market a simple yet effective X-ray shield which not only removes all danger of the operator, but also allows the rays to be directed as required. The part of the X-ray tube from which the X-rays usually emerge is covered with a shield made of a special rubber composition

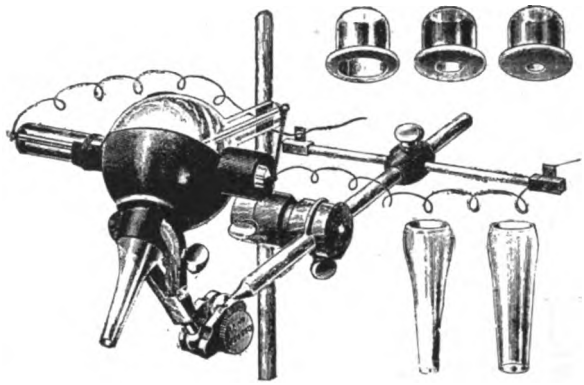

FIG. 9—COX'S X-RAY SHIELD.

which has been carefully selected from the results of extended experiments. Lead glass tubes or stops fit into this shield; the lead glass entirely stops the X-rays, and they are thus only allowed to pass down the axis of the tube, which may be directed on to any desired point. Since the shield is pliable and soft, there is no danger of breaking the tubes, as there was with the glass shield previously in use. There is no metal anywhere about the shield, and consequently the tendency to perforate the tube is avoided. No special stand is necessary, as the tube can be supported by the shield in any ordinary tube holder.

MORGANITE CARBON BRUSHES.

AT the present time all large generators are provided with fixed brushes, which must be made of some substance such as graphite, which interposes an appreciable resistance at the contact between the brush and the commutator segments. It has been proved, however, that where the resistance is chiefly required is at the edge of the brush which leaves the commutator segment; resistance at the other edge of the brush is not only unnecessary but harmful. For these reasons brushes are made by the Morgan Crucible Co., Ltd., Battersea Works, London, which are constructed so that the contact resistance between brush and commutator is very low at one edge and higher at the other, the resistance being graded between the extremes. The low resistance side can be distinguished by the fact that the coating of copper extends over its entire surface, while the high resistance edge has a coating only on that portion usually making contact with the holder.

AUTOMATIC FIRE EXTINGUISHER.

AUTOMATIC devices for extinguishing fires are of the greatest possible utility, provided they are certain in their action and do not require constant attention. The "Expansion" Sprinkler and Fire Alarm, made by The Expansion Sprinkler Syndicate, Ltd., 66, Hatton Garden, E.C., appears to fulfil these requirements. A test recently carried out at the works of Messrs. William Fiddes & Sons, Ltd., Torry Saw Mills, Aberdeen, and witnessed by the Lord Provost Walker, and a committee of influential citizens, proved perfectly satisfactory.

A copper wire is employed to hold a weighted lever in position by means of a small trigger. One end of this lever encircles a glass bulb, which is in direct communication with the sprinkler pipe, and is carried in a "head" of the usual form. When the copper wire is exposed to a rise of temperature, due to an outbreak of fire, the expansion and consequent slackening of the wire releases the trigger; the weighted lever, falling, snaps the glass bulb, and the sprinkler is open. The expansion sprinkler is worked on the dry-pipe system, but without the recognised disadvantage of requiring compressed air in the sprinkler supply pipes. The danger of frost acting upon the wet-pipe system, and the certainty of eventual corrosion and scale, are too well known to require special mention; although the alternate dry-pipe system, which is frequently used, and in which the water is kept back by means of compressed air, has distinct advantages, it undoubtedly has its own drawbacks. The problem of constructing a dry-pipe system with no compressed air in the sprinkler pipes has, heretofore, baffled solution, but the inventors of the "Expansion" claim to have successfully solved it. Combined with the sprinkler, a fire alarm operates simultaneously; and it is claimed that the complications arising from excessive length of electrical wiring, multiplication of electric contacts, with the risk of their failure from dust or dirt, and the number of different batteries, with all the uncertainties attaching to the arrangement, have been overcome in the case of the "Expansion" alarm.

THRELFALL'S GAS-VELOCITY GAUGE.

IN many industries it is necessary to measure the flow of gas through a tube with a fair degree of accuracy. In the past this has been a matter of considerable difficulty, since ordinary meters would have to be much too large in order to measure the volumes of gases frequently used. Mr. Threlfall has perfected an arrangement for measuring the velocity of a gas, which is made by the Cambridge Scientific Instrument Company. This apparatus comprises two tubes, which enter into the pipe through which the gas flows, one tube (Fig. 10) being straight and perpendicular to the length of the tube, and the other bent at right angles, its open end facing the flowing gas. Each tube is connected with a separate vessel, as shown in Fig. 10; the lower parts of these vessels are put into communication by a pipe, and contain water. It will be seen that the gas in the bent tube (called the Pitot tube) must be at rest; and as the gas flowing up to its mouth has a velocity, say v, the pressure inside this tube must be such as would in itself generate a velocity equal in magnitude but opposite in direction to v. Hence the difference of level (h) of the water in the two vessels must be such that—

$$v^2 = 2gh \text{ or } v = \sqrt{2gh}.$$

A research recently carried out at the National Physical Laboratory shows that, in practice—

$$v = 1{\cdot}03\sqrt{2gh}.$$

(see p. 303.)

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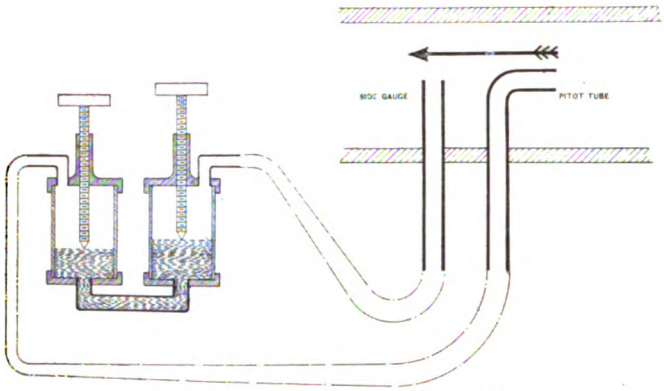

FIG. 10.—THRELFALL'S GAS-VELOCITY GAUGE.

When oil of density d is used in place of water, the velocity is given by the equation—

$$v = 1{\cdot}03\sqrt{2gdh}.$$

In Threlfall's arrangement the vessels containing the water or oil are provided with micrometer screws which can be adjusted so that their points just touch the surfaces of the liquid ; hence the head of water can be accurately measured. The micrometer screws and the water-gauge are shown separately in Fig. 11.

THRELFALL'S GAS CALORIMETER.

SOME years ago the value of coal gas depended almost entirely on its luminosity when burned, but at the present time the use of mantles has rendered the luminosity of the gas much less important, while the calorific value needs to be carefully taken into consideration. The increasing use of gas as fuel for gas engines emphasises this aspect of the question still more. Hence an apparatus for continuously measuring the calorific value of a gas has been greatly needed, and this need has been met by Mr. Threlfall in the apparatus shown diagrammatically in Fig. 12. The gas, after passing through a governor and a meter, is burnt at the bottom of a vertical tube lagged with a non-conductor of heat. The waste gases from the flame rise through the interior of this tube and heat water which descends through a zig-zig tube in the manner shown. The flow of water is carefully regulated so as to be constant, and its temperature before and after receiving heat from the waste gases of the flame is recorded from moment to moment by means of platinum resistance thermometers connected with a Callendar recorder. Thus the heat communicated to the water in a given time becomes definitely known ; and since practically the whole of the heat from the flame is imparted to the water, the calorific value of the gas which is burnt can be determined.

IMPROVED BASE FOR MOUNTING TROLLEY ARMS.

THE trolley-arm base represented in Fig. 13 is made by Messrs. Harper, Phillips and Company, Limited, of Albion Foundry, Grimsby. This base is for attaching to the covered decks of tramcars, and is made with a total height only of 4 ft. from the underside of the base-plate, thus allowing the largest amount of clearance for passing under low bridges. The base is so designed that the same pressure is exerted on the trolley wire at the highest and lowest levels of the arm. This constant pressure is obtained in the following manner. As the spring force increases by compression, it is arranged that its leverage of action on the pivoted arm shall proportionately diminish as compression increases and *vice-versâ*, thus enabling a nearly constant moment of effort to be maintained. All parts of this base are constructed of cast steel ; the wearing parts, which consist of a double ball race at the top and the bottom of the vertical axis, are carefully hardened. The bottom ball race is made as large as six inches in diameter. All the bearing parts can be adjusted by screwing the cap, which can be locked at any required position. One lubricator supplies lubricant to all the bearing parts. When required, this base is supplied with an electrical insulated contact, which allows the trolley arm to be spun round and round the vertical axis without twisting the cable.

HUMIDIFYING AND DUST-COLLECTING PLANT.

FIG. 14 represents a humidifying and dust-collecting plant recently patented by J. Barron, of 25, Whitehall Road, Leeds, and S. Kitson Green, of 53, Bruce Street, Wellington Road, Leeds. The dust-laden air is driven by a fan into a vertical shaft provided with baffle-plates, over which a continuous stream of water flows. Thus the air has to pass through several sheets of water, and so becomes thoroughly humidified, while all the dust and dirt is removed from it. This plant has been specially designed to provide a self-

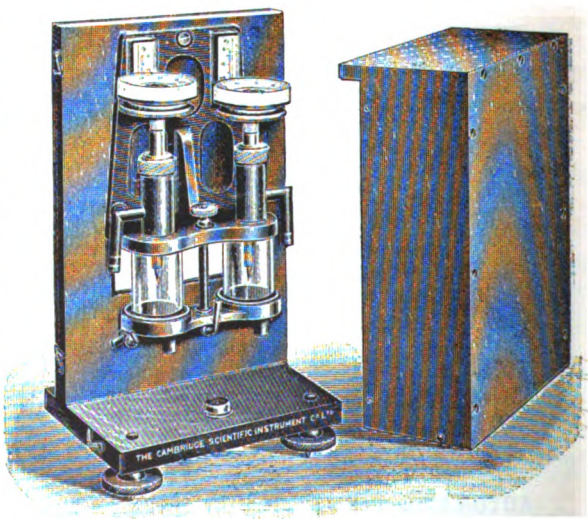

FIG. 11.—MICROMETER TUBES FOR THRELFALL'S VELOCITY GAUGE.

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contained apparatus, of simple and durable character, whereby the dust-laden air from malt-dressing and other similar machines may be effectively cleansed and purified.

ADVERTISING BY "NEW TWINKLING SOCKET."

ADVERTISING by means of an effective electric sign has been greatly handicapped up to the present time by the high initial cost of the installation suitable for this purpose, on account of the expensive automatic switches required and the large amount of wiring necessary. The Electrical Company, Ltd., 121–125, Charing Cross Road, London, W.C., have lately put on the market a special socket which obviates the necessity for special installation, thereby reducing the first cost to an absolute minimum. This special socket is one that can be fixed into ordinary lampholders, and can be used for incandescent lamps of 10 or 16 c.p. and 110 or 220 volts. The socket is such that when the current is switched on, each lamp is cut in and out quickly and continuously at equal intervals of time. If the complete sign is fitted with a number of these special sockets, a most effective result is obtained, each lamp being cut in and out independently of every other lamp, the effect being that the whole sign appears to be twinkling or flickering.

SEAHAM HARBOUR CONTRACT.

MESSRS. GRAHAM, MORTON & Co., Engineers and Contractors, have just secured the contract for the installation of an extensive boat-loading plant for Seaham Harbour. There are several interesting features about this coal-handling plant, and a full description of its design, construction, and erection would doubtless be of interest to our readers when the carrying out of the order has been accomplished; this we hope to give in a future issue. It is sufficient here to observe that, by an arrangement of the eight coal shoots constituting part of the design, an allowance is made for the rising and falling, occasioned by the tide, of the boat loading up.

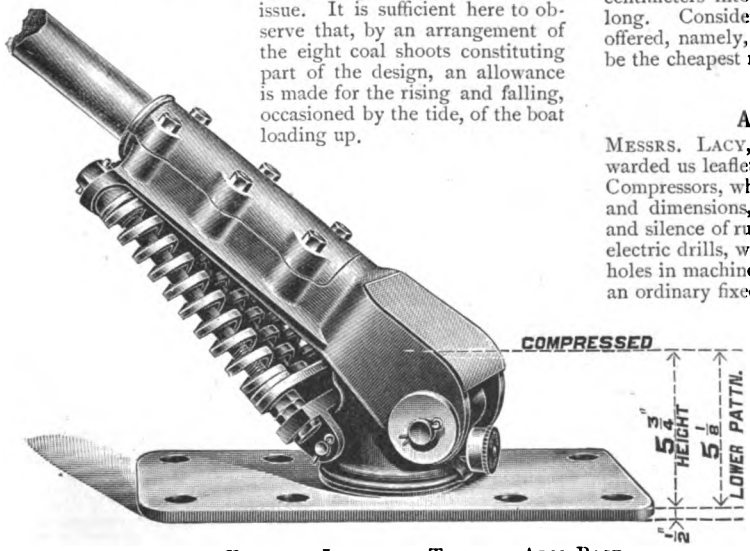

FIG. 13.—IMPROVED TROLLEY-ARM BASE.

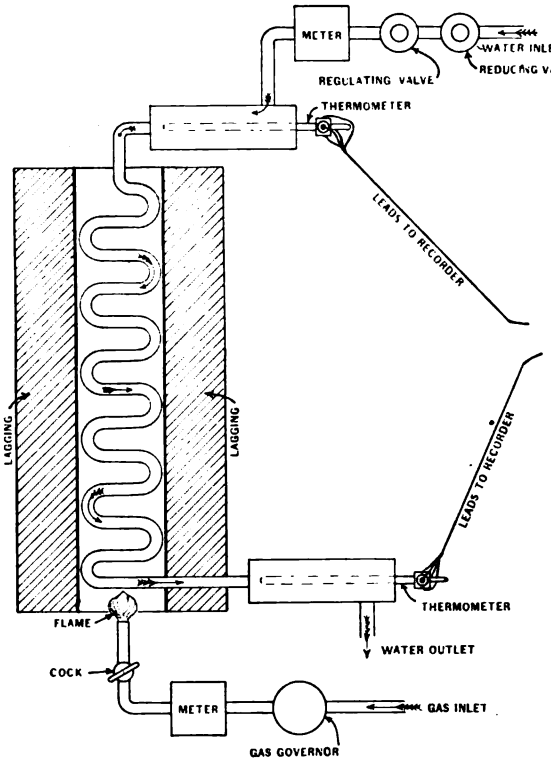

FIG. 12.—THRELFALL'S RECORDING GAS CALORIMETER.

A RULER FOR TECHNICAL INSTITUTIONS.

MESSRS. RELFE BROTHERS, LTD., of 6, Charterhouse Buildings, E.C., have placed on the market a very useful boxwood rule, which should be largely used in all technical institutions. The rule is divided into inches and centimeters, the inches being again divided into eighths, tenths, and twelfths, and the centimeters into millimeters. The rule is ten inches long. Considering the low price at which it is offered, namely, 48*s.* per gross, it may fairly claim to be the cheapest rule of the kind on the market.

AIR COMPRESSORS.

MESSRS. LACY, HULBERT & Co., Ltd., have forwarded us leaflets describing their Boreas Patent Air Compressors, which are characterised by small weight and dimensions, simplicity of design and efficiency, and silence of running. The same firm supply portable electric drills, which should be very useful for drilling holes in machinery, boilers, bridges, roofs, etc., where an ordinary fixed drilling-machine cannot be used.

ELECTRIC LIFTS.

MESSRS. ARCHIBALD SMITH & STEVENS, Janus Works, Queen's Road, Battersea, forward us a most interesting pamphlet dealing with electric lifts. Much original information is given, of a character not usually published. All tables are brought up to date. The first part

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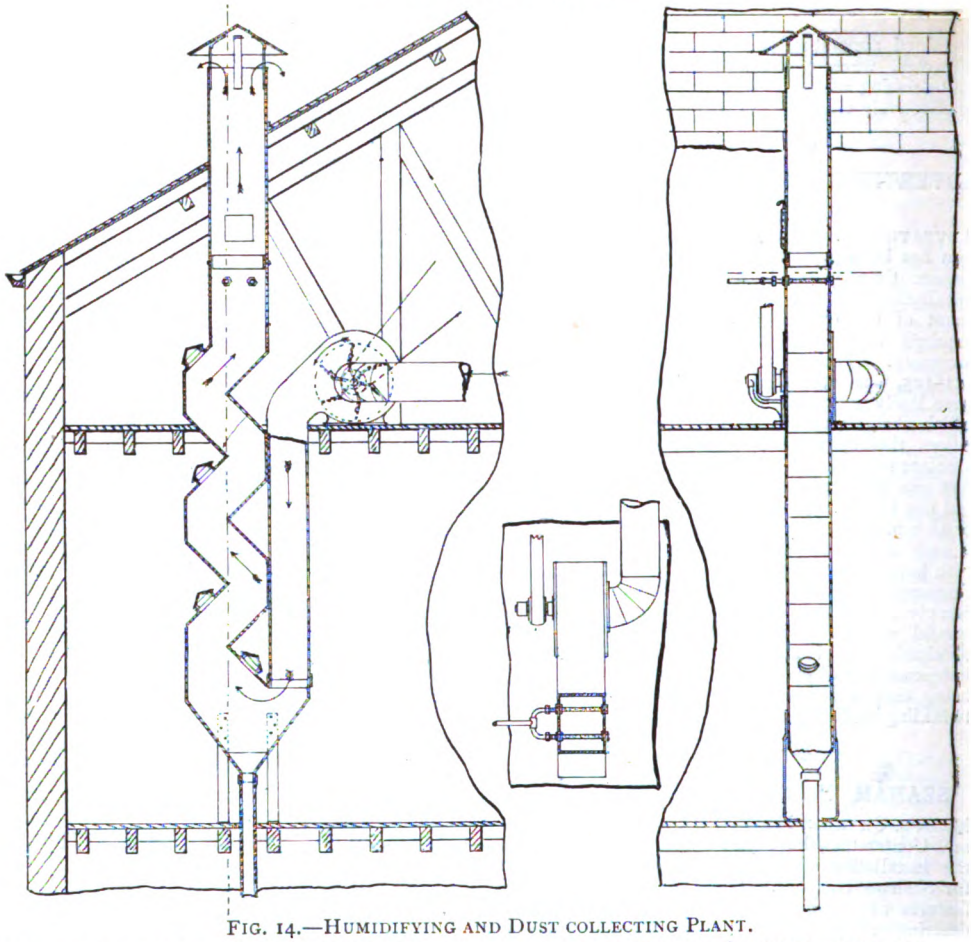

FIG. 14.—HUMIDIFYING AND DUST COLLECTING PLANT.

of the pamphlet deals with the subject of lifts from a scientific and engineering point of view.

THE CLINOGRAPH.

THE Clinograph is a set square made in two parts. One part comprises the two rectangular edges, while the other part, termed the *blade*, is hinged to the rest of the appliance, and forms the inclined edge. With one of the fixed edges resting against the T-square, the blade can be readily set to any required position, and the friction at the hinge is sufficient to hold the blade firmly in position while in use. For drawing parallel lines it is slid along the T-square to any part of the drawing paper. For perpendicular or symmetrical lines, after being set, it is turned with its other edge against the T-square, or with its other face on the paper, as the case may be, after which it is slid into any position as before. Since one edge always rests against the T-square, the discomfort attending the ordinary methods of drawing inclined lines is avoided, and such work is greatly facilitated, whilst at the same time greater accuracy is secured. It is very useful for drawing section lines and for shading generally. The Clinograph is made by Messrs. W. H. Harling, 47, Finsbury Pavement, E.C.

A NEW TIME-LIMIT SWITCH.

AT the Holborn and Finsbury Electrical Exhibition, on the stand belonging to Messrs. Johnson & Phillips, was exhibited a novel form of overload time-limit switch made by Messrs. Griffiths & Biliotti. A heating coil, in series with the current to be controlled, is placed in a brass cylinder, along with a reservoir with an elastic diaphragm. The reservoir is closed and contains ether. Heat radiated from the coil causes the ether to expand, and when the heat radiation attains a certain definite value, a rod attached to the diaphragm of the reservoir is moved outwards far enough to trip the switch. Normally 3½ watts are dissipated by the coil. With a 25 per cent. overload a switch opens the circuit within a range of from twenty to sixty minutes, according to requirements. With a 50 per cent. overload the circuit is opened in seven to twenty minutes. With 100 per cent. overload the circuit is opened in five minutes.

NERNST LAMPS.

THE Electrical Co., Ltd., 121–125, Charing Cross Rd., W.C., have just issued their latest catalogue dealing with improvements in the Nernst lamp. The lamp itself and its various fittings are fully described. The same firm issue a number of leaflets illustrating the application of electric driving to weaving mills, the various accessories for this purpose being fully dealt with.

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Reprinted from "Technics," November, 1904.

LECTURE-NOTES AND HOME EXERCISES.

By FRANCIS C. FORTH, Assoc. R.C.Sc.I., Principal of the Municipal Technical Institute, Belfast.

IT is generally conceded that students should prepare and retain a written record, more or less complete according to circumstances, of the instruction given at lectures. In addition, the majority of teachers of science and technical subjects consider it desirable that some time outside class hours should be devoted to answering questions and working out calculations: this is particularly desirable in the case of evening classes, since there the teacher, as a rule, has an all too limited time at his disposal for imparting instruction, and consequently every lesson, if it is to be thoroughly effective, must be reinforced by strenuous effort at home on the part of the student. This home work should be executed on some plan possessing the merit of being at once systematic, convenient for the student, and admitting of ready checking and verification by the teacher.

The method commonly used does not lend itself to a satisfactory solution of the last-named condition, *viz.*, the preservation of the notes in a form which can be readily examined by the teacher with the minimum of inconvenience. The practice pursued in many evening classes is somewhat as follows:—The student takes down notes of the instruction given in a book, which may be of a pattern adopted generally throughout the institute, or, where no regulation as to pattern exists, the book may be of any size or shape. At the conclusion of the lesson it is usual to set exercises which the students are expected to work at home, where also such notes as possess a permanent value are transferred by the student from his rough notebook into a book of more enduring form. At the next meeting of the class the exercise book is handed to the teacher, who gives the student a fresh set of home exercises, which, with the accompanying notes, are then entered in a second book. This latter book is handed to the teacher at the succeeding lesson, when the first book is returned, corrected, to the student. If a student attends classes in a number of subjects, he requires a couple of home work books for each; thus the number of books he requires may become inconveniently large. An obvious disadvantage arising from this alternation of home work books is that, as the notes of lessons are not consecutively arranged, they are, as a consequence, unfavourably placed for ready reference.

It is customary for teachers to insist upon a specified pattern and size of book being used for home exercises; should no regulation exist upon this point, the difficulties of the teacher are much increased, owing to the miscellaneous assortment of books that are handed in. As to the use of books at all, various objections exist. Evening students who are compelled to proceed direct from work to their class, owing to lack of time to go home, find that books are troublesome to carry, the result being that the

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worked exercises are often left at home. The teacher, too, finds the handling of a collection of thirty or forty such books no light matter; the mere carrying of them is a labour, whilst opening them at the proper pages in order to examine the work occupies a considerable time. Further, in the case of teachers who find only part employment at technical institutes, the home work books have either to be taken home by the teacher for examination and correction, or they are left at the institute, and the exercises checked at some time less convenient than could be chosen if the students' labours were at hand throughout the week.

The difficulties just detailed have made themselves markedly felt at the Municipal Technical Institute, Belfast, since its establishment in the year 1901; the resulting inconveniences became so great with the rapid increase in the number of students (now nearly 5,000), that at the beginning of the session 1903-1904 it was decided to adopt a uniform system of dealing with lecture notes and home work exercises in all classes which could be brought under a uniform system.

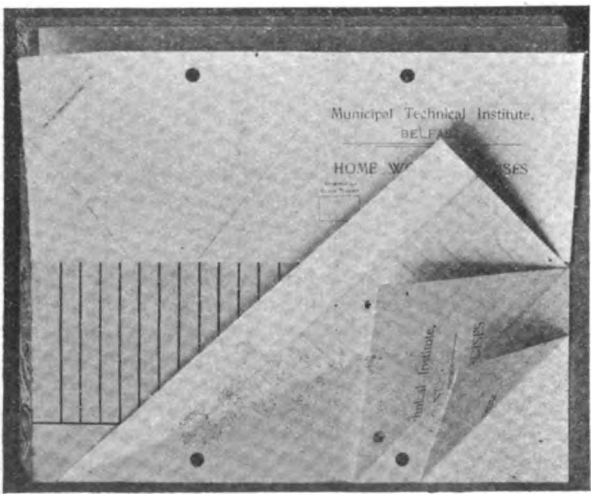

FIG. 1.—WRITING BLOCK.

As the plan followed has proved thoroughly satisfactory, it is thought that a brief account of the system may be of interest to the readers of TECHNICS.

With the object of obviating the disadvantages incidental to the use of books, it was decided to make use of some arrangement of separate or at least easily detachable, sheets, provided that the drawbacks incidental to the use of loose sheets could be overcome. The first step was to obtain a quantity of blocks or pads resembling those used by artists. An illustration of one of these blocks is shown in Fig. 1. Some of the upper sheets have been folded over, the better to display the general arrangement. Each block is composed of 100 sheets of unruled paper, of a quality about equal to that of ordinary note paper. The sheets measure $8\frac{1}{4}'' \times 6\frac{7}{8}''$, a size of paper known to stationers as "lapost 6-mo." The sheets are glued together along the top edge, allowing them to be stripped off one at a time. The blocks are stiffened by a backing of strawboard. Students who find difficulty in keeping their writing equally spaced and in straight lines can place a ruled sheet supplied to them under the unruled page. If the home work exercise necessitates the making of a sketch, then lines might be inconvenient, and in that case the loose sheet is removed and the plain sheet is ready for sketching upon. As shown in the illustration, each sheet is punched with two holes, to enable it to be filed, in a manner explained later on.

The method of dealing with home work questions is as follows:—Each week the teacher sends to the office the draft of the questions which he purposes setting for his class. The number of copies specified by the teacher is then prepared, the typewriting machine being used for cutting a stencil, and the Neostyle for printing copies from this. The latter machine is rapid in its action, and enables the copies to be produced with the minimum of trouble and expense. It is calculated that the cost of stencil, typist's time, paper, ink, etc., averages about eightpence per set of homework papers prepared. The questions are printed on paper of the same size as the sheets of the blocks, and are punched with holes for filing purposes. At the ensuing lesson the questions are distributed amongst the class. By this method no time is lost in dictating questions, or writing them on the blackboard; and, moreover, the teacher is assured that the students have correct copies of all the examples.

When working exercises, the student commences on the top sheet of the block, stripping off each sheet when filled, and slipping the ruled leaf under the next sheet. Usually two or three sheets suffice for the questions set at any given lesson. The exercises completed, the student pins the

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sheets together at the upper left-hand corner. The papers are then folded once, the student makes the requisite endorsement on the back of the last sheet used, and at the succeeding lesson hands his work to the teacher. Thus the teacher obtains from his class a small bundle of papers, resembling a number of sheets of notepaper. This bundle can be quite easily put into the breast pocket of the coat. When these papers have been examined and marked, they are returned to the student at the following lesson. The student is expected to take them home, and to file them in the manner now to be described.

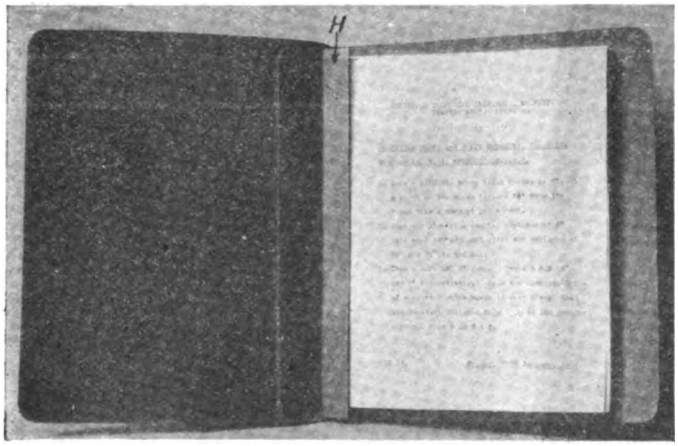

FIG. 2.—TO ILLUSTRATE METHOD OF FILING.

The filing cover used is shown in Figs. 2 and 3. The cover is made of stiff paper and has a hinge H (Fig. 2), to the back of which are secured two flexible metal pins P and P_1 (Fig. 3). The letters MM indicate a metal binding piece, whilst G and G_1 are metal guards holding the pins flat against the binding-piece. The filing operation is exceedingly simple. The guards G and G_1 are slipped along the binding piece in the directions shown by the arrows, when the pins can be bent upright and the binding-piece lifted off. Next, the sheets to be filed are turned face downwards and threaded on to the pins, the binding-piece is replaced, the pins bent outwards and downwards, and the guards slipped back into position so as to lock the pins: the whole operation takes only a few seconds. These files were made for us to a special size by the Stolzenberg Patent File Company.

The question of whether notes taken in class should be re-copied into a home work book is one on which some difference of opinion exists amongst teachers. On account of the time required, the practice of re-copying lecture notes is not encouraged at this institute. Students are advised to take their notes of lectures on the sheets of the block, and to subsequently file them, the order of filing for any given lesson being as follows: (1) Lecture notes; (2) home work question sheet; (3) worked exercises. This gives a complete history of each lesson.

The attachment of the sheets by this filing process is found quite satisfactory for all ordinary purposes. Of course, if a student at the close of a course of lectures desires to have his notes bound in regular book form, it is quite easy for him to have this done.

It was thought at first that the system, being an innovation, might not be taken up readily by teachers and students; but the convenience of the method has been so great that the students now like it very much, and the teachers are well satisfied with it. Looked at from the student's point of view, it will be seen that the purchase of one block at the opening of the session provides the necessary preliminary supply of paper for all the classes joined: formerly it was obligatory to buy two home work books for each subject, in addition to the general notebook, at the beginning of the course. From the teacher's point of view, the convenience of handling the papers is very great, and this in itself has sufficed to commend the system to the teaching staff.

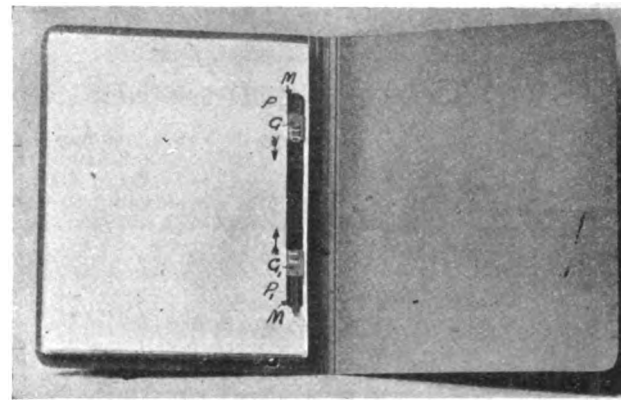

FIG. 3.—DETAILS OF METHOD OF FILING.

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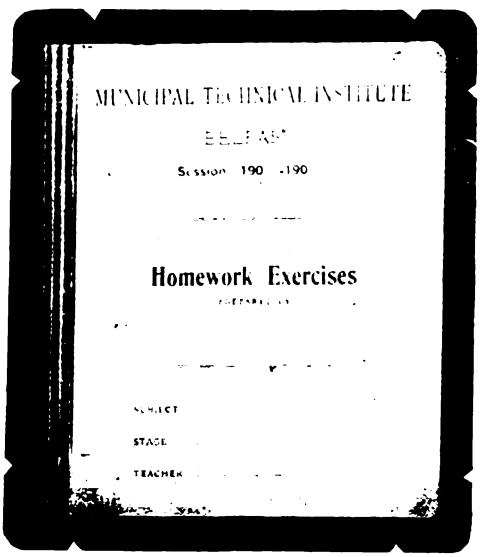

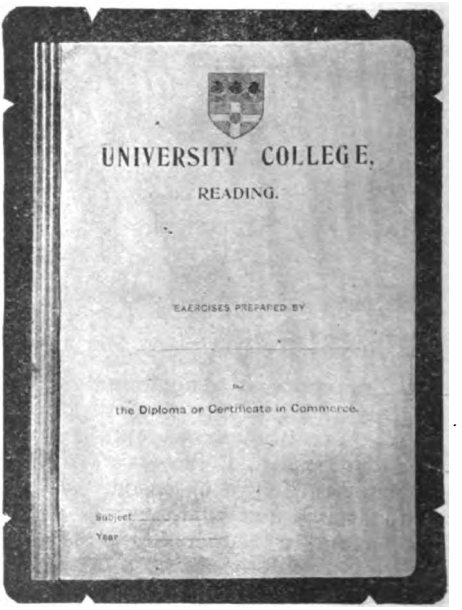

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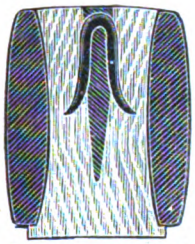

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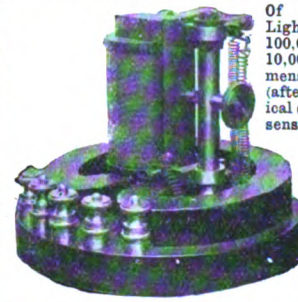

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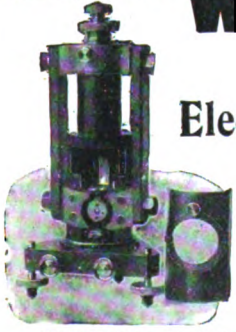

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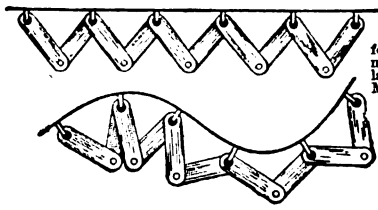

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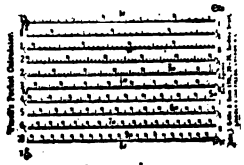

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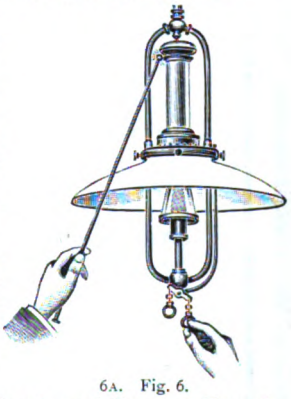

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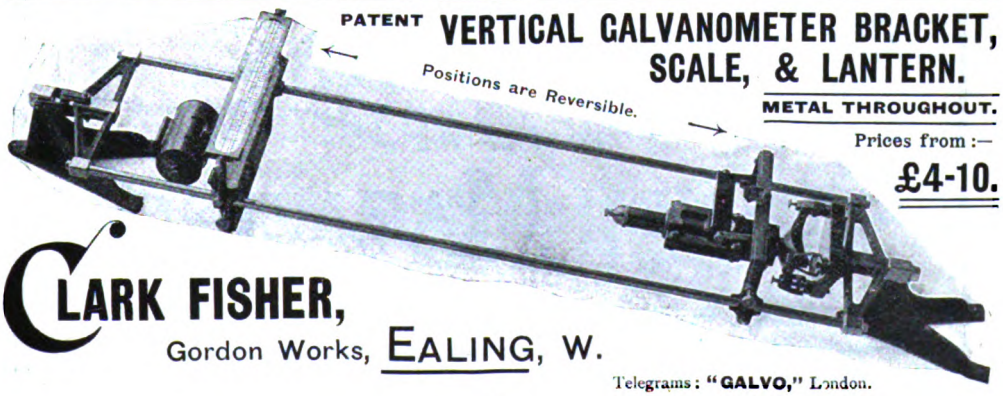

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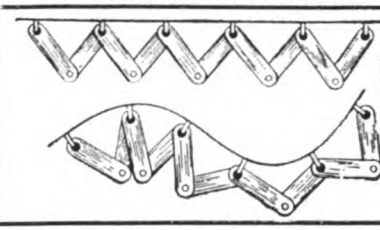

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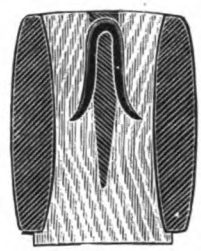

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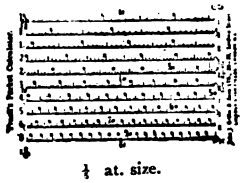
3/1 POST  FREE **3/1**

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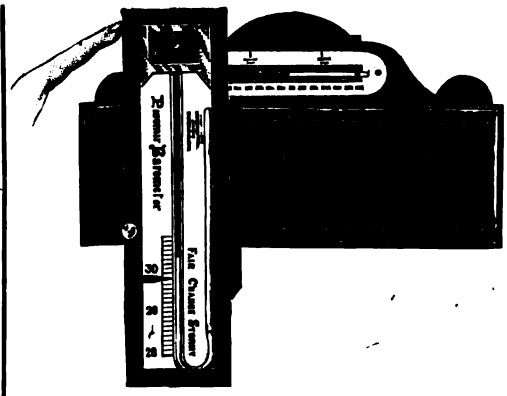

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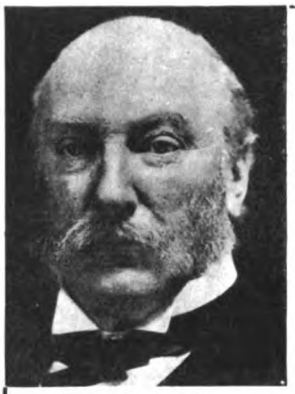

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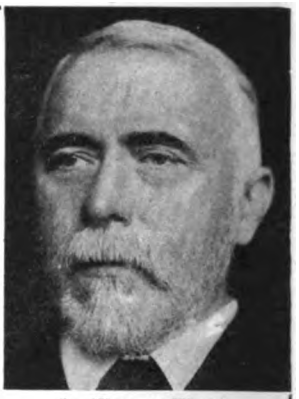

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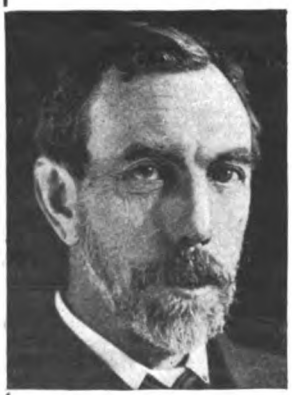

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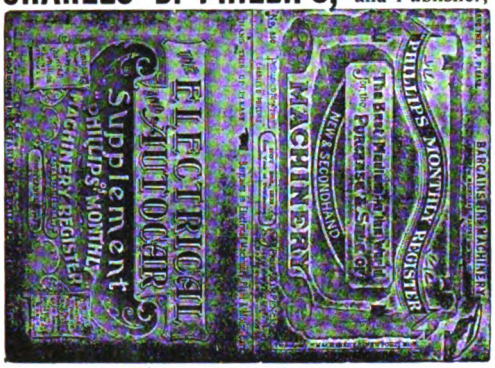

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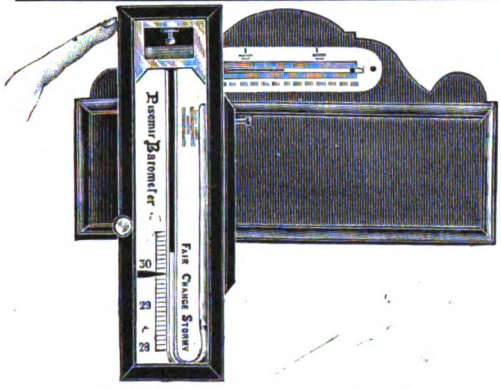

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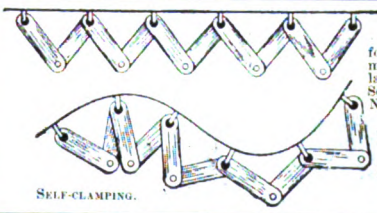

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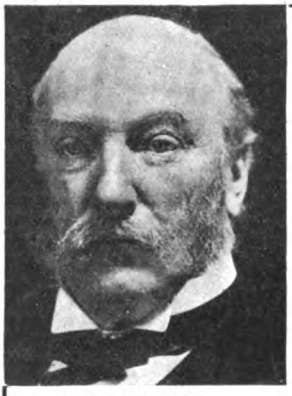

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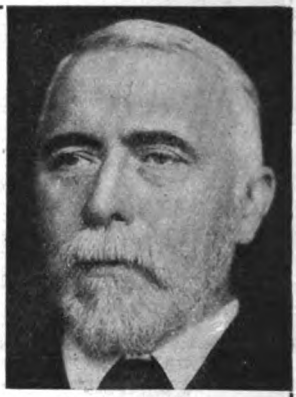

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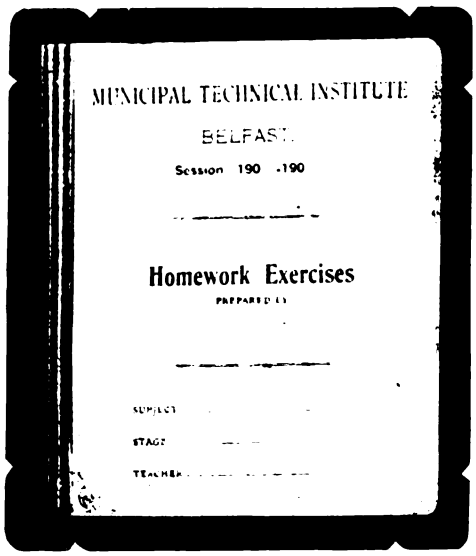

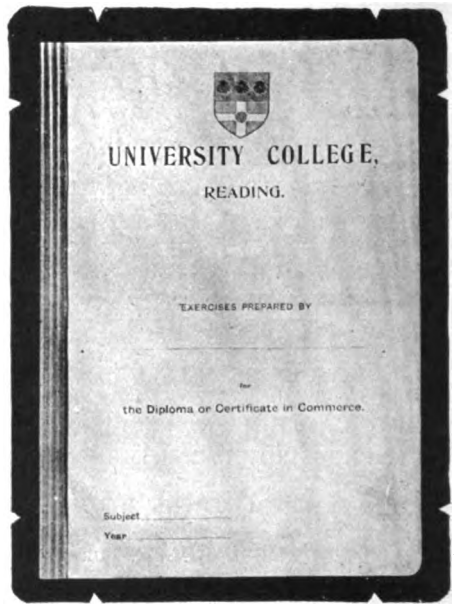

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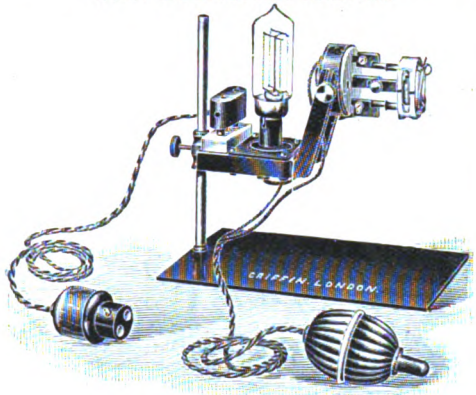

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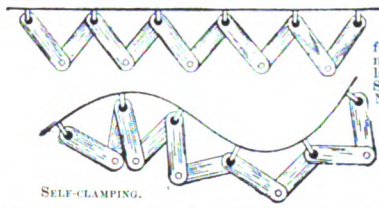

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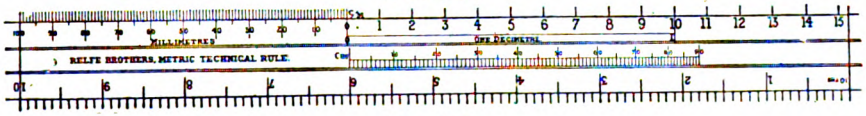

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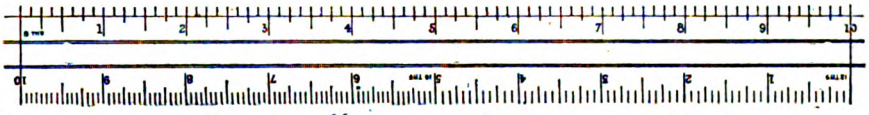

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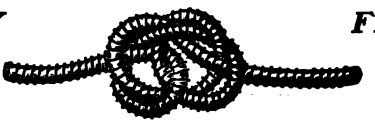

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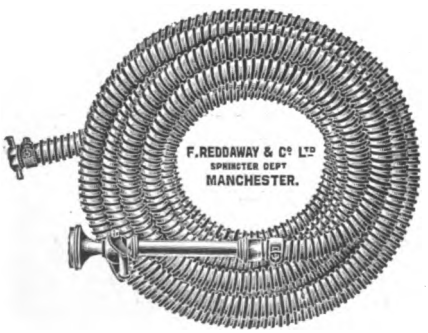

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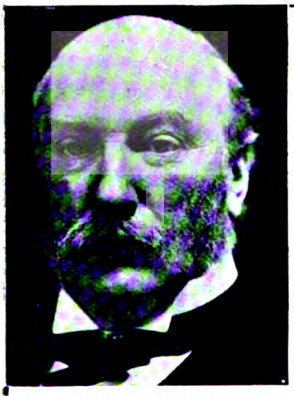

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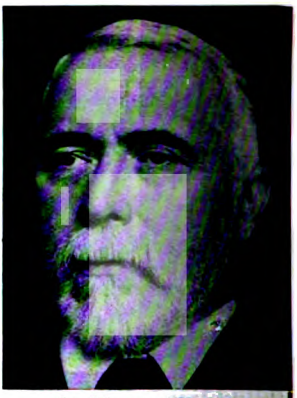

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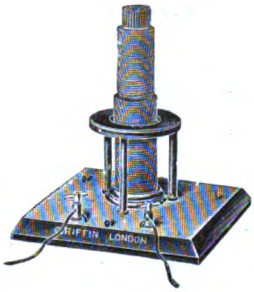

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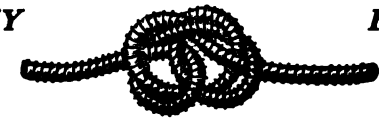

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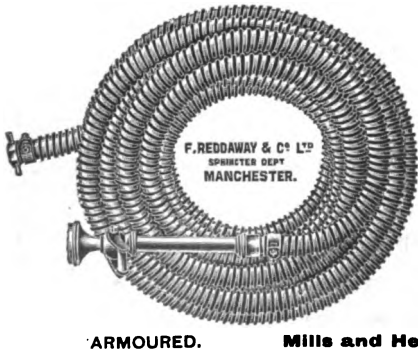

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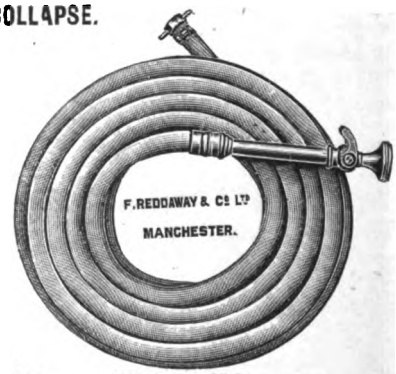

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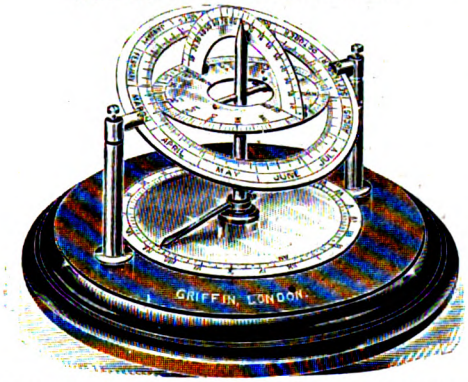

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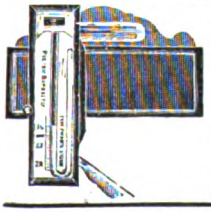

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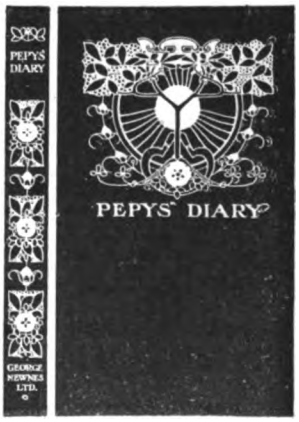

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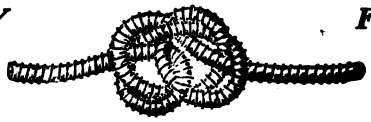

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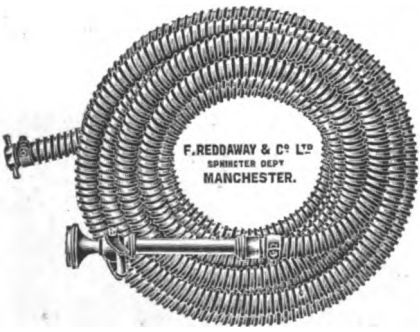

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A MAGAZINE TO AID TECHNICAL PROGRESS.

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